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TEST AND EVALUATION OF A PILOT TWO – STAGE PRECIPITATOR FOR JET ENGINE TEST CELL EXHAUST GAS CLEANING

AT

NAVAL AIR REWORK FACILITY

NAVAL AIR STATION

JACKSONVILLE, FLORIDA

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357800

& constructors inc.

DEPARTMENT OF THE NAVY
SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
2144 MELBOURNE ST., P. O. BOX 10068
CHARLESTON, S. C. 29411

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Yours very truly,

W. L. BROWN, P.E.
Head Specifications Branch

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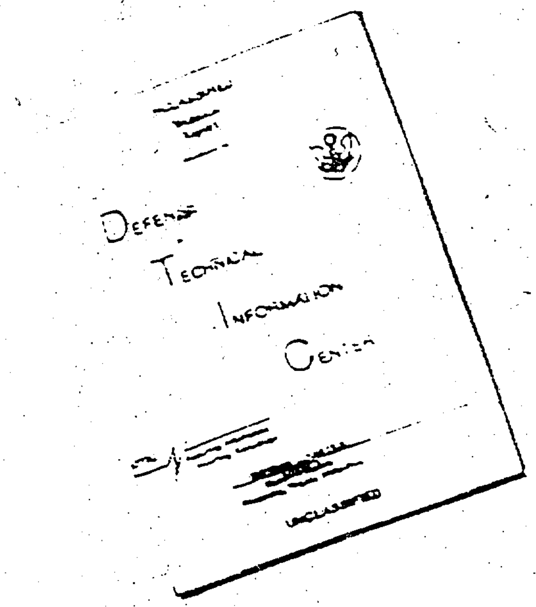

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100 Summer Street, Boston, Ma. 02110

September 14, 1976

Commanding Officer
Southern Division
Naval Facilities Engineering Command
2144 Melbourne Street
Charleston, South Carolina 29411

Attention: Code 406

Gentlemen:

Test and Evaluation of a
Pilot Two-Stage Precipitator
for Jet Engine Test Cells
Contract N62467-74-C-0161

Attached is one copy of a letter from American Air Filter Co. authorizing reproduction of AAF Drawing 835-A which is contained in our report on the Pilot Precipitator Evaluation.

Very truly yours,

D. G. Munson

DGM:bd
RN: 6183-003

Enc.

August 26, 1976

Mr. James A. Ferner
Project Manager
United Engineers & Constructors, Inc.
600 Park Square Building
Boston, Massachusetts 02116

Dear Mr. Ferner:

Permission is hereby granted to reproduce American Air Filter Company Drawing DEV-835A, in line with your request to our Mr. John Ashe.

Please be sure that AAF receives credit for this drawing.

Sincerely,

Robert C. Braverman

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TEST AND EVALUATION OF A PILOT TWO – STAGE PRECIPITATOR FOR JET ENGINE TEST CELL EXHAUST GAS CLEANING

Prepared for:

NAVAL AIR REWORK FACILITY
NAVAL AIR STATION
JACKSONVILLE, FLORIDA

(11) APR 1976

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PRINCIPAL CONTRIBUTORS TO THIS REPORT:
J. A. FERNER – PROJECT MANAGER
D. G. MUNSON – MECHANICAL ENGINEER

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LB

united engineers & constructors inc.
100 Summer Street, Boston, Ma. 02110

April 26, 1976

Department of the Navy
Southern Division
Naval Facilities Engineering Command
Charleston, South Carolina 29411

Gentlemen:

Test and Evaluation of an
Electrostatic Precipitator for
Jet Engine Test Cells
Naval Air Rework Facility
Jacksonville, Florida
Phase II - Contract N62467-74-C-0161

We are pleased to submit herewith our report on the Test and Evaluation of a Two-Stage Precipitator used for Jet Engine Test Cell Exhaust Gas Cleaning. The efficiency tests were conducted on a prototype of the precipitator installed at the Black Point Test Cell, Naval Air Rework Facility, Jacksonville, Florida.

We conclude that the precipitator will operate satisfactorily in the environment of the test cell exhaust stack and that its particulate removal capability is comparable to that of the crossflow scrubber concept now being applied to test cell exhaust gas cleaning. Capital costs for a precipitator system providing this performance are estimated at $1.40-$1.70 per ACFM of test cell exhaust flow depending on test cell size. Direct operating costs are estimated at $65-$130 per engine test depending on engine size.

Should the overall owning and operating costs of the precipitator concept compare favorably with those of the crossflow scrubber, we recommend that final performance testing of the prototype be completed using the EPA Method 5 technique. This should be done prior to a decision on full scale application.

We wish to acknowledge the assistance and participation of personnel associated with the following organizations:

April 26, 1976

Southern Division - Naval Facilities Engineering Command,
Charleston, South Carolina
Naval Air Rework Facility - Jacksonville, Florida
American Air Filter Co., Inc. - Louisville, Kentucky

This report has been prepared under Naval Facilities Engineering Command Contract N62467-74-C-0161.

Very truly yours,

J. A. Ferner
Project Manager

Approved by:

J. H. Fullerton
Vice-President
General Engineering Division

JAF:bd
RN: 6183-003

INDEX

TABLE OF CONTENTS

INTRODUCTION

United Engineers and Constructors Inc. was retained under NAVFACENGCOM Contract N000025-72-C-0037 to study available means for the abatement of air pollution caused by operation of Naval jet engine test facilities. The findings of the study, issued in August 1973, were that the use of fuel additives, the retrofit of smokeless combustors and the installation of gas cleaning equipment were potential means of controlling particulate emissions from the cells. Additives and smokeless combustors were found to require additional development leaving exhaust gas cleaning as the only technology then available for emission control. A two-stage electrostatic precipitator was recommended as the most viable alternative to a concept then being actively developed, the cross-flow wet scrubber.

Due to the unique nature of the application and the high cost of full-sized equipment, it was recommended that a bench scale precipitator be tested to confirm performance and establish size parameters. Such a prototype unit was subsequently installed at Black Point test cell No. 1, Naval Air Rework Facility, Jacksonville, Florida and underwent a sequence of performance and operating tests under the supervision of UE&C.

This report summarizes the results of the test program and provides data on the economics of applying a full-scale system to a jet engine test cell.

SECTION 1

SCOPE OF WORK

1.01 This report summarizes the results of the test program, offers an evaluation of those results and discusses their implication with regard to the technical and economic feasibility of applying the two-stage electrostatic precipitator to test cell exhaust gas cleaning.

Specific objectives of the test program were as follows:

- Confirm that the equipment will operate satisfactorily in the environment of the test cell exhaust stack.
- Establish the maximum gas velocity and minimum field depth at which the equipment will meet performance requirements.
- Document equipment performance using source testing techniques established as acceptable by the Environmental Protection Agency for the particular source application. These techniques are also identical to those used in testing the cross-flow scrubber concept and thereby should produce results which are directly comparable.
- Establish operating cost parameters for the equipment.
- Establish capital cost parameters for equipment.

SECTION 2

SUMMARY AND CONCLUSIONS

2.01 Summary

2.01.1 Gas sampling tests were conducted on a prototype two-stage precipitator installed to clean a portion of the exhaust gases from Black Point Cell No. 1 at the Naval Air Rework Facility, NAS, Jacksonville, Florida. The purpose of the test program was to determine the feasibility of full scale application of the precipitator concept to jet engine test cell exhaust gas cleaning.

2.01.2 Equipment testing proceeded in three phases:

- Tests at various exhaust gas throughputs using the equipment manufacturer's standard test method. These tests were conducted for the purpose of establishing design parameters for the equipment.

- Tests at the established design gas throughput using the standard EPA Method 5 test procedure. These tests were conducted for the purpose of documenting equipment performance using test techniques acceptable to regulatory authorities. A second test team, using different test equipment and procedures, performed simultaneous tests in order to obtain correlation between test techniques.

- A repeat of the manufacturer's tests following a period of sustained operation of the equipment. The purpose of repeat testing was to detect any degradation in equipment performance with use.

2.01.3 Results of the initial series of tests performed at the established design conditions are summarized in Table 2-1.

TABLE 2.1

Test Dates	Test Methods	Inlet Concentration (GR/DSCF)	Outlet Concentration (GR/DSCF)	Efficiency (% Removed)
4-14-75 & 4-15-75	Mfg's. Test Method	$41\text{-}43 \times 10^{-4}$	$3\text{-}4 \times 10^{-4}$	91-93
4-17-75 & 4-18-75	EPA Method 5	$32\text{-}73 \times 10^{-4}$	$12\text{-}35 \times 10^{-4}$	51-65
4-17-75 & 4-18-75	Modified EPA inlet; beta analyzer outlet *	$8\text{-}9 \times 10^{-4}$	$4\text{-}7 \times 10^{-4}$	17-55

*Conducted concurrently with EPA Method 5 tests.

2.01.4 Testing of the equipment utilizing the manufacturer's standard method indicated no degradation in equipment performance after approximately 5 weeks of normal operation. Degradation tests using the EPA Method 5 have not been conducted to date due to nonavailability of the test cell.

2.02 Conclusions

2.02.1 The two-stage precipitator will operate satisfactorily in the hot wet environment of a jet engine test cell exhaust stack. A mist eliminator should be installed upstream of the equipment to prevent liquid carry over from the evaporative cooling system.

2.02.2 The lack of correlation in the results of equipment efficiency testing using the manufacturer's procedure and the EPA Method 5 seem attributable to inherent differences in the test methods since data obtained on multiple runs using the same technique are in fair agreement.

In determining compliance with air pollution regulations, the EPA Method 5 data should be used since this data was obtained using equipment and procedures specified by most regulatory authorities.

2.02.3 The particulate removal efficiencies of the two-stage precipitator and the cross-flow scrubber are similar. The precipitator removed an average of 59% of the incoming particulate according to the EPA Method 5 tests. The cross-flow scrubber exhibited a 55% average removal efficiency during an extensive series of tests conducted in conjunction with an earlier test program. The latter testing utilized the same engine, test configuration and methodology as the precipitator testing. Both efficiency figures refer to the particulate removed in the control equipment proper and do not include removal by the spray system. On the basis of the above comparisons, the performance of the precipitator appears to be at least equal to that of the cross-flow scrubber.

2.02.4 The combined efficiency of the evaporative cooling system, which acts as a prescrubber removing 50-60% of the particulate emission, and the two-stage precipitator averaged 86% on the three EPA Method 5 tests. Emissions leaving the equipment were well below any established standard.

2.02.5 Capital costs for a pollution abatement system incorporating the precipitator concept would be on the order of $850,000 for a 500,000 ACFM system or $1,690,000 for a 1,200,000 ACFM system based on a 500 FPM design velocity.

2.02.6 Annual operating costs for a pollution abatement system incorporating the precipitator concept can be on the order of $32,000 for a 500,000 ACFM system testing 500 J-79 engines per year or $65,000 for a 1,200,000 ACFM system testing 500, 350 lb/sec engines per year.

2.03 Recommendation

2.03.1 The prototype precipitator and test cell duct is still in place at the Black Point Test Cell. However, the test cell stack has been extensively rebuilt without provision for the test duct penetration and thus additional work would be required prior to resumption of the testing.

The results of the initial testing with EPA Method 5 procedures indicate that the two-stage precipitator and the cross-flow wet scrubber are comparable from the standpoint of performance. We feel that the next logical step should be a comparison of the capital and operating costs of the two systems. Costs associated with the two-stage precipitator concept, estimated on the basis of parameters developed during the test program, are given in this report for two test cell sizes. Cost factors for the cross-flow scrubber should be available from the systems now being installed at the Jacksonville and Norfolk Naval Air Rework Facilities.

Should life cycle costs of the precipitator concept compare favorably with those of the wet scrubber, final performance testing of the prototype should be completed to document performance to the satisfaction of regulatory authorities.

2.03.2 It is evident that test cell exhaust gas cleaning will be an expensive proposition regardless of the type of control equipment installed. Continued work on alternative measures, fuel additives in the near term and clean burning engines in the far term, is certainly warranted. Application of exhaust gas cleaning should be limited to specific cells scheduled to test older engines which, for reasons of performance, cannot use fuel additives.

SECTION 3

DISCUSSION OF TEST PROGRAM AND PROCEDURES

The test program was divided into five phases which are summarized below and outlined in detail in Reference 4.

3.01 Phase I - Manpower and Equipment Scheduling - Two test teams took part in the program. One team, staffed by American Air Filter Inc. the supplier of the prototype, calibrated the exhaust gas draw-off apparatus and performed the type "A" tests described below. A second team, staffed by Jacksonville Naval Air Rework Facility personnel, performed the type "B" tests also described below.

A third test team, staffed by personnel from the Aircraft Environmental Support Office of the Naval Environmental Protection Support Service (NEPSS), conducted tests simultaneously with the type "B" tests. These tests were not a part of the NAVFAC test program but were run for the purpose of comparing results obtained by the NARF Jax team with those obtained by the NEPSS team which used a different type of sampling equipment.

3.02 Phase II - Equipment Checkout and Pretest Calibration - The pretest calibration phase consisted of calibrating the venturi section differential to the exhaust gas flow through the test system as measured by a pitot tube traverse. The venturi reading would then be used to compute gas flow rate during the type "A" testing to determine optimum velocity.

The procedure, as originally constituted, called for the utilization of a throttling damper installed at the outlet of the prototype to vary gas flow. However, the unexpectedly high kinetic energy of the

exhaust gas entering the test duct rendered this procedure unworkable due to the inability of the ductwork to contain the static pressure developed by the throttling action.

As a result of the above, it was necessary to vary the gas flow rate through the test duct by means of varying the orifice area at the inlet of the duct section. New pitot tube traverse holes were drilled in the 1 ft. x 1 ft. sections of the duct upstream of the venturi section in order to produce higher and therefore more accurate velocity head readings. Four calibration runs were performed using orifice areas of 12 in.^{2}, 18 in.^{2}, 24 in.^{2} and 36 in.^{2}. The orifice area vs gas flow relationship provied to be linear producing test flows of 2517, 3826, 4732 and 7334 ACFM respectively.

3.03 Phase III - Initial Performance Testing - This phase of the test program, conducted during the period of April 7-18, 1975 and June 4-6, 1975, included both type "A" and type "B" efficiency tests. The type "A" testing served the dual purposes of establishing equipment compatibility with the test cell exhaust gas and determining the maximum exhaust gas throughput velocity at which the unit would operate with a satisfactory collection efficiency. The type "B" tests were conducted to document equipment performance and, additionally, to provide data which could be directly compared to data accumulated during a previous test program associated with the cross-flow wet scrubber prototype.

3.03.1 Type "A" Test - A total of eight (8) type "A" tests were run during the initial performance phase. The type "A" tests utilized American Air Filter's standard test procedure which called for single-point sampling at the inlet and outlet of the prototype. The average velocity through the ductwork (as de..rmined by the pretest calibration runs) was

used to establish sampling rates which would approximate isokinetic conditions at the sample probe nozzle.

Tests were conducted at each of the four operating points corresponding to gas velocities of 172, 262, 323, and 501 FPM through the prototype. Unit efficiency was calculated after each run utilizing NARF laboratory facilities. Using 90% by weight collection efficiency as performance criteria, the maximum allowable velocity through the prototype was established as approximately 500 FPM.

3.03.2 Type "B" Tests - A total of seven (7) type "B" tests were run during the initial performance phase. Three tests were performed immediately following the type "A" tests and utilized the same J-79 engine. The remaining tests were performed approximately six (6) weeks after the initial tests.

The type "B" tests allowed computation of both particulate removal by the prototype and particulate removal by entrainment in the unevaporated portion of exhaust gas cooling water. The standard EPA [3] Method 5 procedure was utilized to determine particulate removal from the gas stream. A 20-point grid was sampled at the inlet and outlet of the unit with sample flow rate adjusted at each point to produce isokinetic conditions at the probe nozzle. Both solid and liquid particulates were collected and recorded. Particulate removal by water entrainment was determined by establishing the drain flow rate and concentration of particulates in the effluent. This concentration was then multiplied by the ratio of drain flow rate to exhaust gas flow rate to obtain a number comparable to the gas stream samples.

The procedures used in the type "B" testing conducted by NARF personnel duplicated those used by the same personnel in testing the wet crossflow scrubber model [2].

3.03.3 NPESS Tests - The NEPSS tests were conducted concurrently with the type "B" tests run April 17-18, 1975. Inlet sampling was conducted using an Aerotherm high volume EPA Method 5 particulate sampler which is similar to a standard EPA train that has been scaled up in size to allow high volume sampling. Outlet sampling was conducted using a Lear Seigler PM/Argos I continuous particulate mass emission analyzer. This device measures the attenuation of beta radiation by particulate collected on a filter tape and converts this to a measure of the particulate mass.

3.04 Phase IV - Normal Operating Runs - The purpose of this phase of the program was to obtain an indication of equipment durability under normal operating conditions. The prototype was operated during normal engine testing sequences between the dates of June 6, 1975 and July 13, 1975.

3.05 Phase V - Final Performance Testing - Performance testing was conducted following the normal operating period in order to detect any degradation in equipment performance with time. Two type "A" tests were run on July 15, 1975 at the design velocity of 500 FPM through the precipitator. The performance indicated by these tests was essentially the same as that indicated by the initial service of type "A" tests.

This phase of the test program also called for additional type "B" testing in order to obtain "degradation" data using testing techniques acceptable to pollution control authorities. However, to date, the Black Point cell has not been available to support such tests due to the heavy schedule of production engine tests and extensive modification of the test cell stack.

SECTION 4

RESULTS OF EQUIPMENT TESTING

4.01 Equipment Reliability - In general, the equipment proved capable of operating satisfactorily when handling the test cell exhaust gas. Several operating problems did, however, occur during the course of the test program indicating design modifications recommended below.

4.01.1 Excessive Arcing - The location of the exhaust gas draw-off duct was such that a large amount of cooling water was entrained in the gas entering the prototype. This caused a substantial amount of arcing within the precipitator. Excessive arcing is detrimental to equipment operation in three ways:

(1) Short circuiting occurs between collecting plates thus reducing the effective strength of the electrostatic field between plates. Since it is this field that forces the ionized particulates towards the collecting plates, the overall effect of reducing the strength of this field is reduced particle deposition and reduced collection efficiency.

(2) Average electric power consumption is increased and high peak power inputs induced by the short circuiting are encountered.

(3) The power peaks occassionally cause the circuit protection equipment contained in the precipitator control units to shut the equipment down.

Although entrained moisture should be less of a problem at the top of the test cell stack, it is recommended that any full scale installation be equipped with a mist eliminator upstream of the precipitator.

4.01.2 Failure of High Voltage Leads - Early in the test program during the velocity calibration runs, the equipment was tripped off the line several times due to failure of the insulation on the high voltage wiring supplying the ionizing and collecting electrodes. All failures occurred inside the precipitator casing where the wires were exposed to appreciable moisture.

The equipment was rewired using wire with a better grade of insulation (silicon-insulated) and no further problem was experienced. It is recommended that the high grade wire be specified for any full-scale installation.

4.01.3 Power Supply and Voltage Control Components - A diode in one of the power pack assemblies failed during the initial testing phase and was replaced. Failure was apparently due to a manufacturing defect. No other problems were experienced with power pack components throughout the duration of the test program.

4.01.4 Ionizer Wire Breakage - Two high voltage (12 kV) ionizers failed during the second series of type "A" tests. Replacement of ionizer wires is an item of routine maintenance discussed in Section 5.

4.02 Equipment Collection Efficiency - Results of the type "A" and "B" tests are summarized in Table 4.1. Raw test data and details of test and data reduction procedures are given in Appendix A-1 for the type "A" tests and in Appendix A-2 and Reference 2 for the type "B" tests. NEPSS test results are reported separately in Reference 5.

4.02.1 Type "A" and "B" Tests - Type "A" tests run between April 9 and April 14 established a maximum operating velocity through the unit at 500 FPM for a collection efficiency of approximately 90% and two collecting

TABLE 4.1

RESULTS OF EFFICIENCY TEST RUNS

	Engine	Type Test	Gas Flow in Test Duct (ACFM)	Velocity thru Prototype (FPM)	Inlet Part. Conc. (GR/DSCF)	Outlet Part. Conc. (GR/DSCF)	Collection Efficiency Prototype (%)	Collection Efficiency Prototype & Spray Water (%)
4-9-75	J-79	A	2517	172	0.0045	0.0008	82.22	-
4-9-75	J-79	A	2517	172	0.0018	0.0002	88.89	-
4-10-75	J-79	A	3828	262	0.0019	0.0001	94.74	-
4-11-75	J-79	A	4732	323	0.0031	0.0001	96.77	-
4-11-75	J-79	A	4732	323	0.003	0.0002	93.33	-
4-14-75	J-79	A	7334	501	0.0041	0.0003	92.68	-
4-14-75	J-79	A	7334	501	0.0043	0.0004	90.70	-
4-15-75	J-79	A	7334	501	0.0023	0.0005	78.3[1]	-
4-17-75	J-79	B	7148[2]	488.5[2]	0.00730[3]	0.00354[3]	51.5	
					0.00866[4]			77.8
4-18-75	J-79	B	6622[2]	452.6[2]	0.00392[3]	0.00120[3]	64.9	
					0.00902[4]			90.73
4-18-75	J-79	B	6980[2]	477[2]	0.00321[3]	0.00127[3]	60.4	
					0.00822[4]			88.89
6-4-75	J-52	B	6462[2]	441.6[2]	0.00191[3]	0.00344[3]	-80.1	
					0.00163[4]			2.82

Date	Engine	Type Test	Gas Flow in Test Duct	Velocity thru Prototype	Inlet Part. Conc.	Outlet Part. Conc.	Collection Efficiency	
							Prototype	Prototype & Spray Water
			(ACFM)	(FPM)	(GR/DSCF)	(GR/DSCF)	(%)	(%)
5-5-75	J-52	B	6523[2]	445.8[2]	0.00156[3]	0.00192[3]	-23.08[1]	
					0.00155[4]			33.52[1]
5-6-75	J-52	B	6566[2]	448.8[2]	0.00192[3]	0.00240[3]	-25.00[5]	
					0.00163[4]			32.40[5]
5-6-75	J-52	B	6599[2]	451[2]	0.00199[3]	0.00238[3]	-19.6[5]	
					0.00149[4]			31.6[5]
7-15-75	J-79	A	7334	501	0.001882	0.000272	85.54	
7-15-75	J-79	A	7334	501	0.003492	0.000248	92.88	

(1) Tests run with one of two banks out of service.

(2) Based on average of measured inlet and outlet velocities. Measured inlet velocity exceeded measured outlet velocity on all "B" type tests except second run on 4-18-75.

(3) Includes solid particulates from probe and filter and liquid particulates from impingers.

(4) Particulates collected in sump drains normalized to a dry gas flow basis. Corrected for 10 ft^2 duct.

(5) Tests run with entire precipitator de-energized and out of service.

banks in series. Highest efficiency points were experienced at velocities in the 250-350 FPM range which was the anticipated design velocity range of the equipment. However, it was found that velocity could be increased to the 500 FPM range before efficiency fell off to 90%. The test of April 15 was run at 500 FPM with only one of the two series fields in service and indicated an efficiency of 78%. Ratioing this performance to the two-field performance, it was deduced that a single field in series would not meet performance criteria at any of the velocities tested. On the basis of the series of tests, equipment rat' was determined by the manufacturer to be as follows:

Face velocity:	500 FPM
Field depth:	Two cells
Efficiency:	90%

Type "B" testing conducted on April 17 and 18 indicated markedly lower efficiencies than the type "A" testing. Calculated precipitator efficiencies ranged from 51.1% to 64.9% averaging 59%. Total system efficiencies, which reflected particulates removed by spray water, ranged from 77.8% to 90.7% averaging 86%.

The data from the type "A" tests can be compared to the type "B" test data for the air sampling (Note 3 in Table 4.1), since both reflect particulate removal in the precipitator only. Inlet concentrations on the type "A" tests ranged from 18-45 x 10^{-4} GR/DSCF which seem to be in reasonable agreement with the type "B" tests which had readings of 73, 39 and 32 x 10^{-4} GR/DSCF respectively. The principal differences in the data appear in the outlet concentrations. The type "A" data indicates 3-4 x 10^{-4} GR/DSCF (4-14-75 runs only) while the type "B" data shows markedly higher concentrations

of 12, 13 and 35 x 10^{-4} GR/DSCF. Since testing was performed under essentially identical conditions, the differences in data apparently stem from the different testing techniques and equipment.

Since the type "B" tests utilize techniques accepted by the EPA and most local authorities and thereby will form the basis of documented equipment performance, NARF personnel undertook to conduct additional tests for the purpose of confirming the initial results. These tests were not run until June 4-6, 1975 due to engine testing requirements and mechanical problems with the Black Point cell.

The June 4 test indicated a precipitator efficiency of -80%. A subsequent test performed with only one field energized indicated an efficiency of -23% and two tests conducted with all power off indicated efficiencies of -25% and -19.6%. All tests were run with a J-52 engine as a pollution source in lieu of a J-79 engine.

Subsequent to the June testing, it was learned that during the interim period between the April and June tests, the blank-off plate which was installed at the sampling duct inlet had become dislodged. This allowed particulate-laden engine exhaust gas to pass through the prototype during normal engine production testing. Prolonged exposure to these exhaust gases could result in particulate buildup on the collecting plates to a point where they would begin to be re-entrained in the gas passing through the unit. This appears to be the only plausible explanation for the negative efficiency readings which are indicative of more particulate leaving the prototype than entering. Since normal operation of the prototype would encompass a washing cycle which would prevent particulate buildup on the plate, the June 4-6 data cannot be considered representative of equipment performance.

The final type "A" tests on July 15, 1975 were run after the prototype had been exposed to exhaust gases resultant from normal engine testing for a period of about 5 weeks. Two tests were run at design flow rate and indicated the same approximate level of performance as the initial test runs (89% efficiency).

As was mentioned earlier, a final series of type "B" tests were to be performed in this phase of the program. However, due to unavailability of the test cell, these tests have yet to be undertaken.

4.02.2 NEPSS Tests - The NEPSS tests were run concurrently with the type "B" tests of April 17-18, 1975. Inlet concentrations measured with the high volume EPA Method 5 train all measured in the range of 8-9 x 10^{-4} GR/SCF. These concentrations are substantially below those recorded in either the type "A" or "B" tests.

Other concentrations measured with the beta attenuation mass analyzer ranged from 4 to 7 x 10^{-4} GR/SCF. These values are below those recorded in the "B" tests and slightly above those recorded in the "A" tests. Overall precipitator efficiency calculated using the inlet and outlet concentrations averaged 38% ranging from 17% to 55%.

4.03 Compliance with Emission Regulations - No specific emissions standards have been established for jet engine test cells; however, a number of standards exist which are broad enough in scope to be considered applicable (1). The most stringent of these regulations is the San Diego Air Pollution Control District Regulation limiting total particulate emissions (solid and liquid) to 0.1 GR/SCF with gas volume artifically corrected to a 12% CO_2 level. For JP-5 fuel, this is equivalent to 0.175 lbs/10^6 BTU heat input. Using this emission rate as criteria and with available test data indicating particulate emissions in the range of 1.0

to 1.3 lbs/10^6 BTU, the requirement for a 90% efficient abatement system was established.

Particulate emissions measured on the inlet side of the precipitator were an order of magnitude lower than those reported in previous test data. Inlet particulate loadings ranged from 0.04 lbs/10^6 BTU to 0.09 lbs/10^6 BTU in the type "A" tests which measured only solid particulates in the gas stream and from 0.24 lbs/10^6 BTU to 0.33 lbs/10^6 BTU in the type "B" tests on the J-79 which measured total particulates in both the gas and water streams. The emissions on the outlet side of the precipitator ranged from 0.002 lbs/10^6 BTU to 0.017 lbs/10^6 BTU in the type "A" tests and 0.025 lbs/10^6 BTU to 0.073 lbs/10^6 BTU on the type "B" tests. Thus, on all tests, emissions were below established standards.

It is not known where emissions from the test engine fall relative to emissions from the entire family of turbojet and turbofan engines. If the average efficiency for the initial type "B" tests of 86% is used as being indicative of system performance, the combined spray and precipitator systems would allow testing of engines emitting up to 1.25 lbs/10^6 BTU without exceeding the San Diego Regulation.

4.04 Comparative Performance - Precipitator vs. Crossflow Scrubber - Both the proposed precipitator and crossflow scrubber system designs use a water quench to cool the test cell exhaust gases prior to treatment. This spray system acts as a prescrubber by entraining and removing particulate from the gases before they reach the control equipment. The type "B" tests, which measured particulate contained in the duct drains upstream of the precipitator and related them to the gas sampling data, indicated that from 55-70% of the total particulate was removed in this fashion. Identical tests

run on a model crossflow scrubber and the same J-79 engine during the period of November, 1973 to February, 1974 indicated approximately 60% removal in the same quench system.

A comparison of the gas sampling data which is representative of the particulate removed in the control equipment alone, indicates an average collection efficiency for the precipitator in the three type "B" tests of 59% (range 51.5% - 64.9%) and an average efficiency for the crossflow scrubber of 55% (range 45% - 65%)[2]. Overall efficiency of the two systems computed on the basis of spray water and control unit removal averaged 86% for the precipitator and 78% for the crossflow scrubber.

On the basis of the above data, the performance of the two systems appears comparable.

4.05 Power Consumption - Power supply to the prototype was monitored at periodic intervals during testing. Excessive peaks were encountered with input current ranging from 4 to 8 amps at 120V AC and averaging approximately 6 amps. Average power input was, therefore, approximately 432 watts (.6 PF) or 0.059 KW/1000 ACFM. The power input was no doubt increased by the large amount of entrained moisture entering the unit. This effect should be rectified by the installation of the moisture eliminator discussed earlier.

4.06 Precipitator Wash Schedule - The precipitator was washed at the completion of the type "B" testing. Cycles with and without detergent addition were run resulting in the recommendation by representatives of the manufacturer that detergent addition be included as part of the wash cycle. Observation of the collecting plates after washing indicated that they remained discolored (black) but no excessive build-up of unremoved particulate.

On the basis of experience during the initial testing phase, a schedule of one wash per week was established as a trial procedure for the interim phase of the test program where the prototype would be operated during normal production testing of engines. Unfortunately, the schedule was not rigorously followed during the interim period and thus no reliable data was obtained relative to the adequacy or inadequacy of washing.

In the absence of field data, the precipitator manufacturer was consulted regarding his experience with similar installations. It is their estimate that with particulate grain loadings in the range experienced during testing, the first collecting field would require washing once per 40 hours of operation and the second field once per 160 hours of operation. This information must be regarded as approximate, however, due to the uniqueness of the application.

The frequency with which the precipitator must be washed is heavily dependent on the emission factors of the engines tested. Since these factors can vary widely, washing schedules will vary widely depending on the engines tested.

SECTION 5

FULL-SCALE SYSTEM DESCRIPTION AND ECONOMICS

5.01 System Description - Design of a full-scale pollution abatement system for a particular cell would be tailored to the requirements of the engines tested. Basic system components are illustrated in Figure 5.1.

5.01.1 Precipitator - The precipitator has five major components: entrained moisture eliminator, fields, washer assemblies, power control cabinets (power packs) and washer control cabinets. The moisture eliminator is of the vertical multi-pass louver design extending across the entire face of the precipitator. The louver will also serve to distribute the flow of incoming exhaust gas. The precipitator fields are comprised of a number of individual cells stacked in vertical (modules) banks perpendicular to the direction of gas flow and supported in a structural frame. Each cell has dimensions of 36" wide, 14" deep and 16" or 20" high. Modules can be configured to suit the stack dimensions of a particular application. Each horizontal row of cells receives an independent power supply (two leads - 12kV and 6kV) which is connected to the outside cell in each row. Interior cells are energized by means of contact strips attached to each cell. The power to each cell is controlled by remotely mounted power packs which consist of transformer, rectifiers, voltage control and circuit protection. Input to the control cabinets is 120V AC single phase and output is 12,000V DC (ionizing fields) and 5800V DC (collecting fields).

The modules containing the precipitator fields will be arranged two in series in the direction of gas flow. Washer assemblies are located on the inlet side of each module. Each washer assembly is approximately 4'-0" wide and extends the full height of the module. During

the wash cycle, three rotating spray nozzles make four vertical passes over the entire height of a four foot wide section of the module. After four passes, the assembly indexes along a horizontal track to the next 4'-0" section and repeats the process until one complete horizontal pass is made. The nozzles travel at a speed of 6 ft/min in the vertical direction and consume 15 GPM while in operation. Cleaning detergent will be added at a rate of 1/2 GPM during the first two vertical passes via a separate pump. Washer assembly travel, water supply and detergent supply are automatically controlled from a remotely mounted control cabinet.

All components in contact with the exhaust stream are enclosed in a gas tight casing top, bottom and sides. Access doors are provided on each side of the washer assembly cavity for inspection and maintenance.

Figure 5.2 illustrates the general arrangement of components. Each 25' X 12' section would be furnished with individual inlet plenum and stack and appropriate turning vanes for gas distribution as determined by a pre-design model study.

5.01.2 Evaporative Cooling System - Test cell exhaust gases would be cooled in a manner similar to the cooling systems now in service in cells which test after-burning engines. Components include a series of spray rings located in the augmentor tube and the base of the test cell stack, control valves for modulation of spray water supply to minimize over spray, spray water pumps and water storage tank.

5.01.3 Water Reclamation System - Excess spray water and the drains from the precipitator wash cycle flow by gravity to a collecting sump where they are pumped to a holding tank designed to provide surge capacity for the relatively large amount of overspray during the after

burner tests. From the holding tank the slurry is pumped through a pressure-leaf filter where suspended particulates are removed and then back to the storage tank for reuse. Water from the wash cycle, one half of which would contain a biodegradable detergent, would be discarded.

5.01.4 Solids Removal and Recovery - Solids are removed from the overspray and wash water by direct filtration. This is a relatively expensive method of solids removal but due to its compactness is suited to the ground space limitations around existing cells. The filter medium is a series of vertical hollow leaves coated with a filter aid. A mixture of particulates and filter aid are deposited on the outside surface of the leaves forming a cake. Collected particulates are removed on an intermittent basis by evacuating the filter, air dyring and vibrating the leaves which deposit the dry cake on a continuous conveyor for collection.

5.01.5 System Controls - The system would operate automatically during the engine test. Operator action would be required in the following areas:

- Turn on power to equipment prior to engine test.
- Remotely monitor (annunciator) systems during test.
- Initiate and monitor precipitator wash cycle.
- Initiate and monitor collected particulate removal from pressure leaf filter and returning of filter to service.

A typical arrangement of system components is illustrated in Figure 5.3.

5.02 Capital Costs - The cost of installing a two-stage precipitator, evaporative cooling system and sludge removal system capable of handling 550,000 ACFM of test cell exhaust gas is estimated to be $850,000. This size installation would be large enough to handle a J-79 (180 lb/sec)

engine with after burner or a TF30 (250 lb/sec) engine without after burner.

Estimated cost of a larger system capable of handling the 1,200,000 ACFM of exhaust which would result during test of a 350 lb/sec turbo fan engine in after burner is $1,690,000. Cost breakdowns are shown in Table 5.1.

The basic precipitator for the 550,000 ACFM unit would consist of eight (8) modules each 24'-8" wide by 12'-0" high. On a test cell with the stack configuration of those at Black Point, these modules would be arranged one wide, two high and two deep (in direction of gas flow) on two sides of the stack. The 1,200,000 ACFM unit would require sixteen (16) modules 24'-8" X 13'-0" arranged two high and two deep on all four sides of the stack. The foregoing represent two arrangements of precipitator surface which appear workable. Module dimensions and physical arrangement can be varied to suit stack configuration and ground space availability at particular cells.

5.03 Operating Costs - Estimated operating costs for the pollution abatement system are summarized below for the areas of consumable utilities, consumable material, maintenance and operating labor.

5.03.1 Consumable Utilities - The overall cost of utilities will vary considerably with the size and type of engine tested and the test duration due to the large cost impact of the evaporative cooling system. Table 5.2 summarizes estimated utilities consumption and cost for a J-79 engine with after burner representative of the 500,000 ACFM cell and a hypothetical 350 lb/sec engine with after burner representative of the 1,200,000 ACFM cell. The basis for quantities listed in Table 5.2 is given in Appendix 3.

An additional utility would be compressed air for drying the pressure filter prior to cleaning. This would amount to approximately 10,000 SCF per cleaning: approximate cost = $2.00.

TABLE 5.1

CAPITAL COST OF TEST CELL POLLUTION ABATEMENT SYSTEMS

	550,000 ACFM	1,200,000 ACFM
Precipitator assemblies incl. cells, washers, moisture eliminator, controls, support frame, casing, breeching and stacks.	$474,200	$1,112,600
Evaporative cooling system incl. water storage tank, spray pumps, piping, nozzles and controls.	$ 71,900	$ 133,000
Water reclamation system incl. sump pump, surge tank, slurry pumps, piping and controls.	$ 26,500	$ 40,200
Pressure-leaf filter assy incl. filter, supports, precoat tank and piping.	$ 65,800	$ 65,800
Electrical work incl. power transformers, motor controls, lighting and wiring.	$ 92,600	$ 134,400
Civil/structural work incl. site work, support steel, walkways, equipment slab and control building.	$118,900	$ 204,400
TOTAL CAPITAL COST	$849,900	$1,690,400

Prices include markups as follows:

Omissions and Contingencies - 15% on all items except precipitator and pressure filters.

Contractors OH&P - 21% on all items.

General Contractors OH&P - 5% on structural and electrical totals.

TABLE 5.2

UTILITIES CONSUMPTION AND COST PER ENGINE TEST

	Source	J-79 w/AB Consumption	J-79 w/AB Cost	350 lb/sec w/AB Consumption	350 lb/sec w/AB Cost
POWER @ $0.3/ KWH	Precipitator Energization	56 KWH	$1.68	146 KWH	$4.38
	Evaporative Cooling Pumps	66 KWH	$1.98	143 KWH	$4.29
	Spray Reclamation Pumps	2.3 KWH	$0.07	4.3 KWH	$0.13
	Precipitator Washer*	0.3 KWH	$0.01	0.9 KWH	$0.03
	TOTAL POWER	124.6 KWH	$3.74	294.2 KWH	$8.83
WATER @ $.35/ 1000 Gal.	Lost Through Evaporation	28,800 Gal.	$10.08	64,500 Gal.	$22.58
	Discarded wash Water**	363 Gal.	$ 0.13	856 Gal.	$ 0.30
	TOTAL WATER	29,163 Gal	$10.21	65,356 Gal.	$22.88

*Precip Washing Power: J79 - $\frac{\text{4.6 KWH/Wash}}{\text{16 Tests/Wash}}$

350 lb/sec - $\frac{\text{14.1 KWH/Wash}}{\text{16 Tests/Wash}}$

**Discarded washwater: J79 - $\frac{\text{5800 Gal/Wash}}{\text{16 Tests/Wash}}$

350 lb/sec - $\frac{\text{13700 Gal/Wash}}{\text{16 Tests/Wash}}$

5.03.2 Consumable Material - Recurring consumable items include detergent for the precipitator wash cycle and filter aid for the pressure filter system.

The material required for the filter aid will fluctuate widely depending upon the amount of particulates filtered and the ratio of filter aid to particulate which must be maintained to provide a porous cake. The amount of particulates collected will be proportional to the emission factors (e.g. dirtiness) of the engines tested. These values apparently can range from the 1.0-1.7 lbs/10^6BTU reported by previous air pollution tests(1) to the 0.16-0.24 lb/10^6 BTU experienced in the Jacksonville tests. Ratio of filter aid to particulate required can range from 0.1 to 1.0 lb F.A./lb particulate. This ratio is empirically derived for a particular installation.

A pressure leaf filter with 800 sq.ft. of filter surface could collect approximately 1400 lbs of particulates between cleanings. Using a 1:1 ratio of filter aid to particulate and 0.1 lbs/sq. ft. from the precoat cycle, a total of 1480 lbs of filter aid would be required for a complete cycle. The cost per cycle would be approximately $44.40 using a $3.00/100 lbs material cost based on an east coast location.

Using conservative emission factors in the 1.0-1.7 lbs/ 10^6 BTU range, it is estimated that a J-79 in a 120 minute cycle would generate 212 lbs of collected particulates and a 350 lbs/sec turbofan in a 137 minute cycle would generate 291 lbs of particulate. This rate of collection would require filter cleaning twice every 12-13 tests with the J-79 or 9-10 tests with the 350 lb/sec engine.

Detergent is supplied at a rate of one part to 40 parts water during one-half of the wash cycle (two of the four passes). Consumption

for one complete wash cycle is therefore:

500,000 ACFM unit: 5,760 Gal X ½ cycle X 1/40 ratio = 72 Gal.

1,200,000 ACFM unit: 12,500 Gal X ½ cycle X 1/40 ratio = 156 Gal.

Using a material cost of $4.00/gallon, the cost per wash is $290 for the 500,000 ACFM unit and $629 for the 1,200,000 ACFM unit. As previously mentioned, washing schedule can vary considerably, therefore, for estimating purposes only it will be assumed that on both systems the first bank is washed every 10 tests and the second bank every 40 tests. This averages to one complete wash every 16 tests for a cost of $18.14 per test for the 500,000 ACFM unit and $39.30 for the 1,200,000 ACFM unit.

5.03.3 Maintenance Costs - Elements of the systems which could be expected to require periodic replacement are as follows:

- Precipitator (per module per year)
  - Fields - Ionizer wire replacement; 100 per year @ $1.70 ea = $170
    - Cell replacement; 3 per year @ $275 ea = $825
  - Power Packs - Transformer replacement; one every four years @ $236 ea = $59
    - Silicon rectifier replacement; one per year @ $26 = $26
  - Washer Assy - Replacement of motors and chain drives after 15 years = $200/15 = $13
  - Washer Control - Miscellaneous component replacement over 15 year life = $1000/15 = $67/year

Total estimated annual material replacement costs per module = $1160. Cost for 8-module 500,000 ACFM installation = $9280. Cost for 16-module 1,200,000 ACFM unit = $18,560.

- Pump Maintenance: Lubrications, seals, etc. = $200/year
- Pressure Filter: Main gasket replacement one per year = $35

- Controls and instrumentation: Estimate of $200/year

In addition to parts replacement, the installation would require routine inspection on a weekly basis. At intervals of approximately 5 years, all cells should be removed and manually washed. It is estimated that this operation would require approximately 4 mandays per module. Allowing one manday per week for routine maintenance, average annual maintenance labor requirements for the two systems investigated would be as follows:

500,000 ACFM: Routine maintenance: 1 md/wk X 52 weeks = 52 md/yr

Major cleaning: 2 md/wk X 8 modules/5 yrs = 32 md/yr

TOTAL: 55.2 md/yr

1,200,000 ACFM: 2 md/wk X 52 wks = 104 md/yr

2 md/module X 18 modules/5 years = 6.4 md/yr

TOTAL: 110.4 md/yr

At an average cost of $75/md, the annual costs for the two systems would be $4140 and $8280 respectively.

5.03.4 Operating Labor - The system is designed to operate automatically with operator action required only to turn on the power supply to the precipitator. An annunciator panel would be provided in the test cell control room to alert operators to any off-normal conditions which may arise. Precipitator washing and removal of carbon sludge from the filter is also highly automated requiring operator action only to initiate the cycles and monitor the precoat operation. In view of the above, we do not anticipate the need for any additional full time staffing to operate the system. A portion of the operators' time would have to be devoted to

supervision of the wash cycle and solids separation processes. This would be in the range of 3 hours per wash/removal cycle assuming full time supervision while the equipment is operating.

5.03.5 Annual Operating Costs - Annual costs are summarized in Table 5.3 for an assumed test cell loading of 500 engine tests per year. Approximately 34% of the above costs represent consumable material used in precipitator washing and solids separation whose useage is basically a function of engine dirtiness.

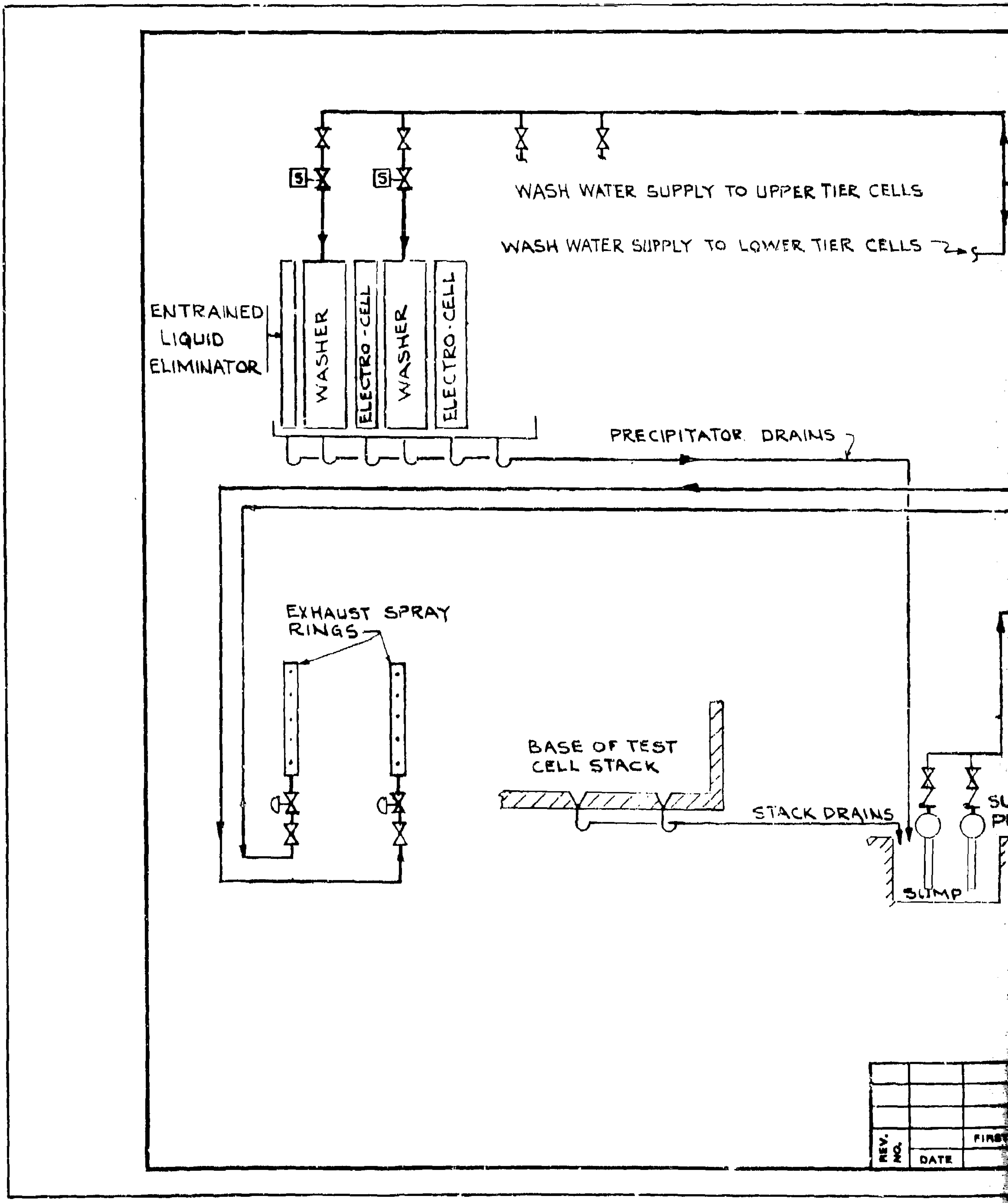
TABLE 5.3

ANNUAL OPERATING COSTS

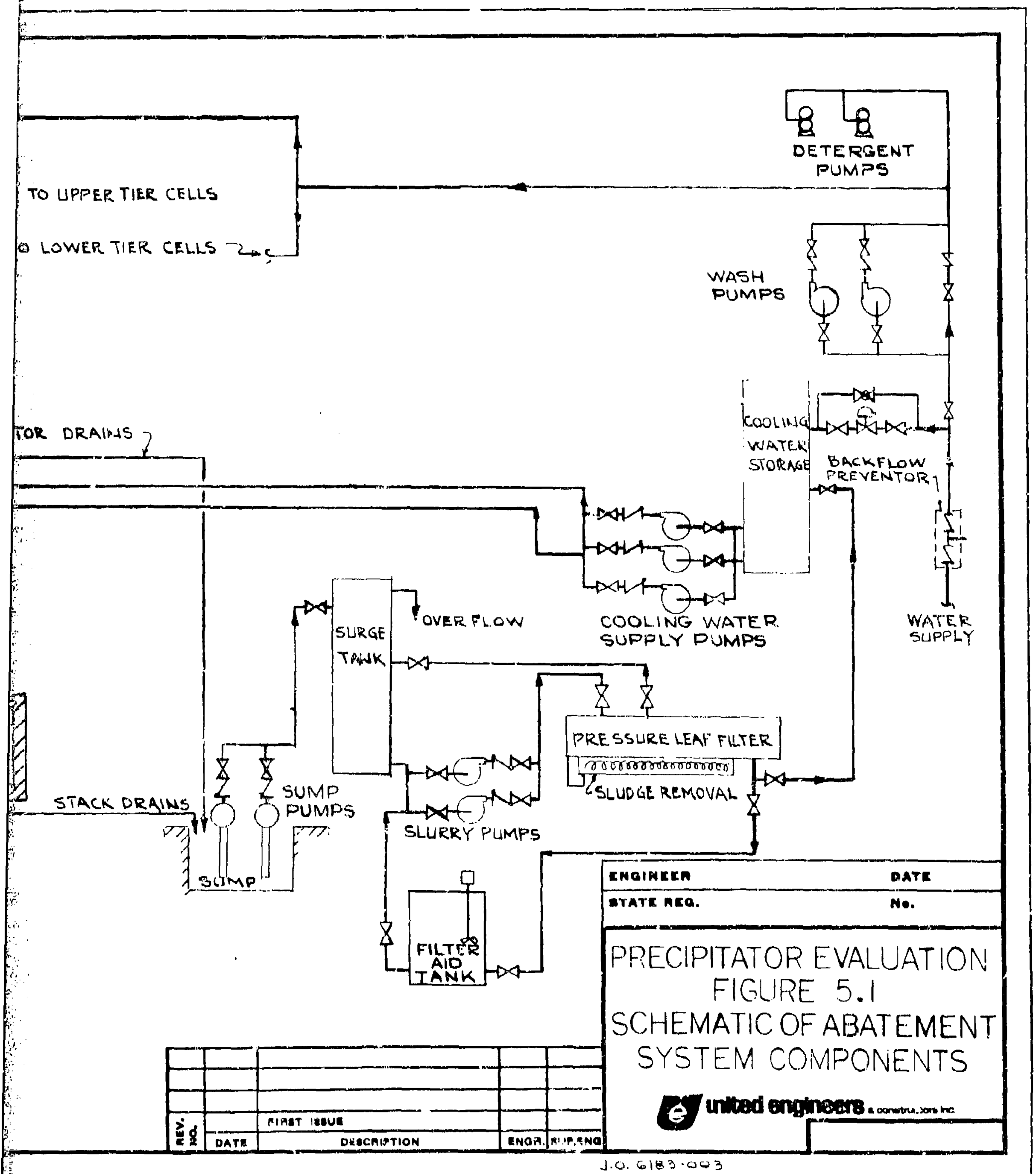
500 ENGINE TESTS PER YEAR

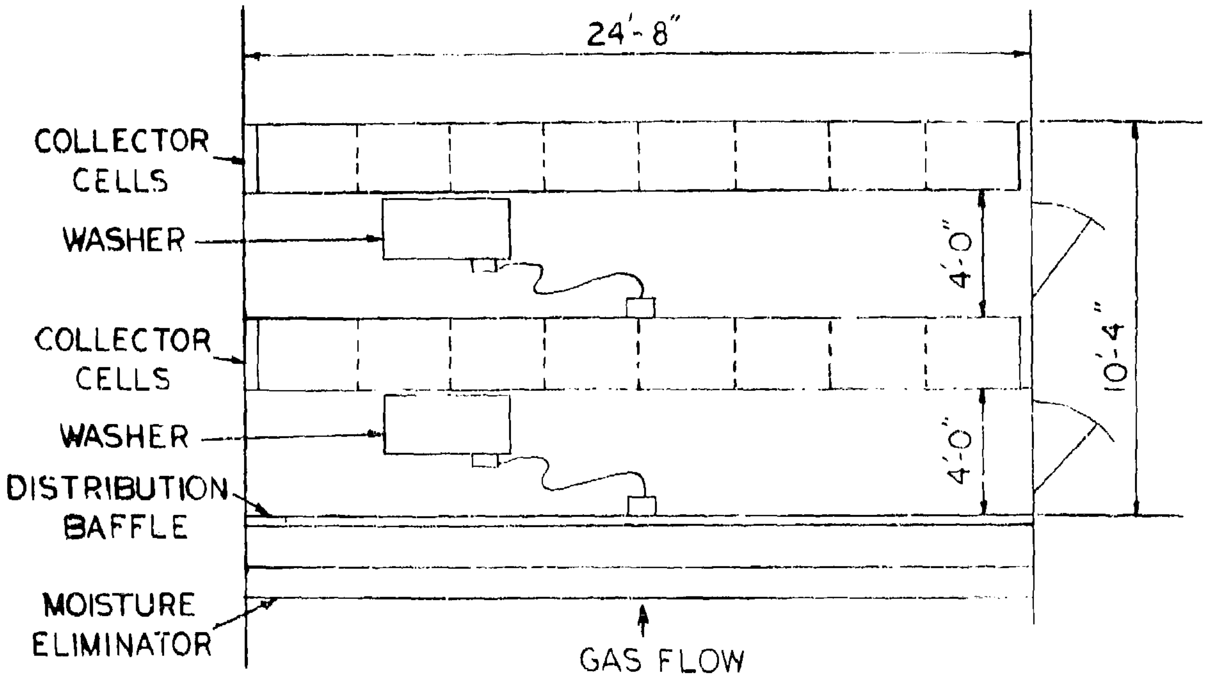
	Item		Consumption	Rate	Annual Cost
J-79 (500,000 ACFM)	Utilities	- Power*	62,300 KWH	$0.03/ KWH	$1,869
		- Water	14.58×10^6 GAL	$0.35/ 1000 G.	$5,103
	Material	- Detergent	2,250 Gal.	$4.00/ Gal.	$9,000
		- Filter aid	61,667 lbs.	$3.00/ 100 lbs	$1,850
	Maintenance	- Parts	----	----	$9,715
		- Labor	----	----	$4,140
	Totals		----	----	$31,667
350 lb/sec (1,200,000 ACFM)	Utilities	- Power*	147,100 KWH	$0.03/ KWH	$ 4,413
		- Water	32.68×10^6 Gal.	$0.35/ 1000 G.	$11,438
	Material	- Detergent	4875 Gal.	$4.00/ Gal.	$19,500
		- Filter Aid	74,000 lbs.	$3.00/ 100 lb	$ 2,280
	Maintenance	- Parts	----	----	$18,935
		- Labor	----	----	$ 8,280
	Totals		----	----	$64,846

* Exclusive of demand charges

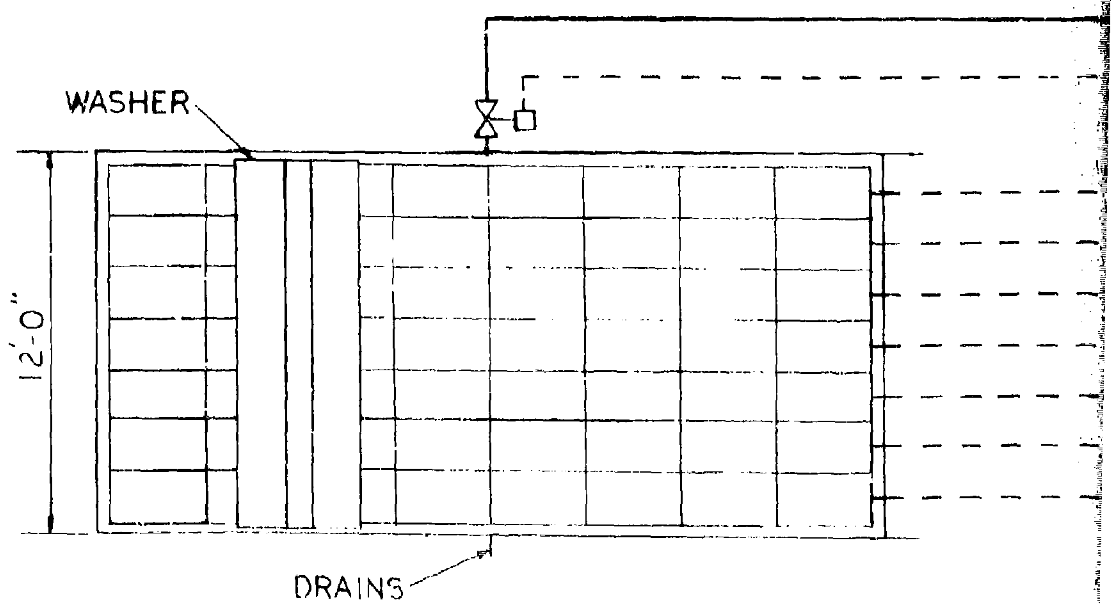


WASH WATER SUPPLY TO UPPER TIER CELLS
WASH WATER SUPPLY TO LOWER TIER CELLS
5
5
ENTRAINED LIQUID ELIMINATOR
WASHER
ELECTRO-CELL
WASHER
ELECTRO-CELL
PRECIPITATOR DRAINS
EXHAUST SPRAY RINGS
BASE OF TEST CELL STACK
STACK DRAINS
SUMP
REV. NO.
DATE


DETERGENT PUMPS
TO UPPER TIER CELLS
O LOWER TIER CELLS
WASH PUMPS
TOR DRAINS
COOLING WATER STORAGE
BACKFLOW PREVENTOR
SURGE TANK
OVER FLOW
COOLING WATER SUPPLY PUMPS
WATER SUPPLY
PRESSURE LEAF FILTER
SLUDGE REMOVAL
STACK DRAINS
SUMP PUMPS
SLURRY PUMPS
SUMP
FILTER AID TANK
ENGINEER
DATE
STATE REG.
No.
PRECIPITATOR EVALUATION
FIGURE 5.1
SCHEMATIC OF ABATEMENT SYSTEM COMPONENTS
united engineers & constructors inc.
FIRST ISSUE
REV. NO.
DATE
DESCRIPTION
ENGR.
SUP. ENG
J.O. 6183-003

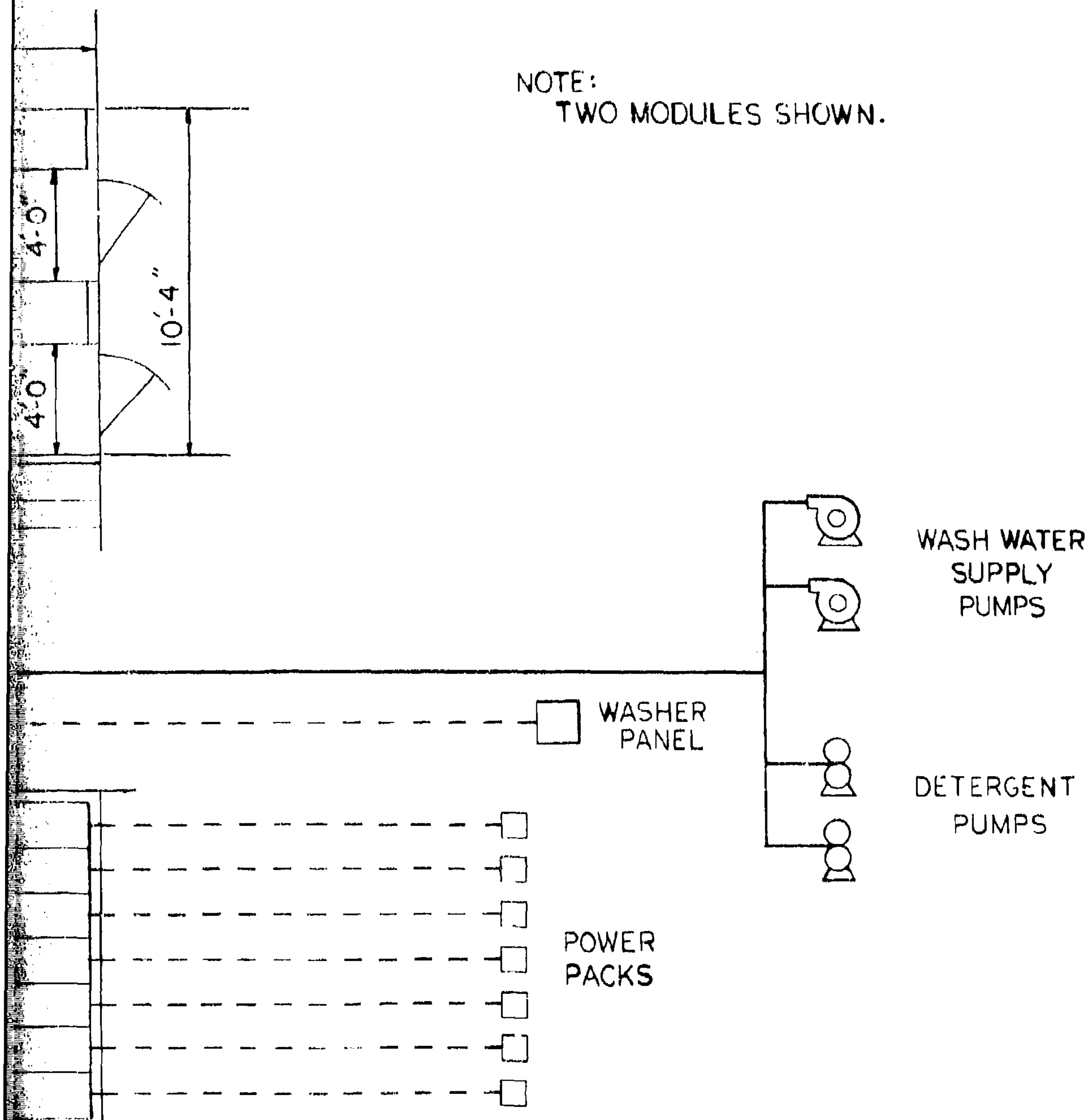


PLAN



FRONT ELEVATION

REV. NO. | DATE | FIRST



PRECIPITATOR EVALUATION

FIGURE 5.2

ARRANGEMENT OF MODULE COMPONENTS

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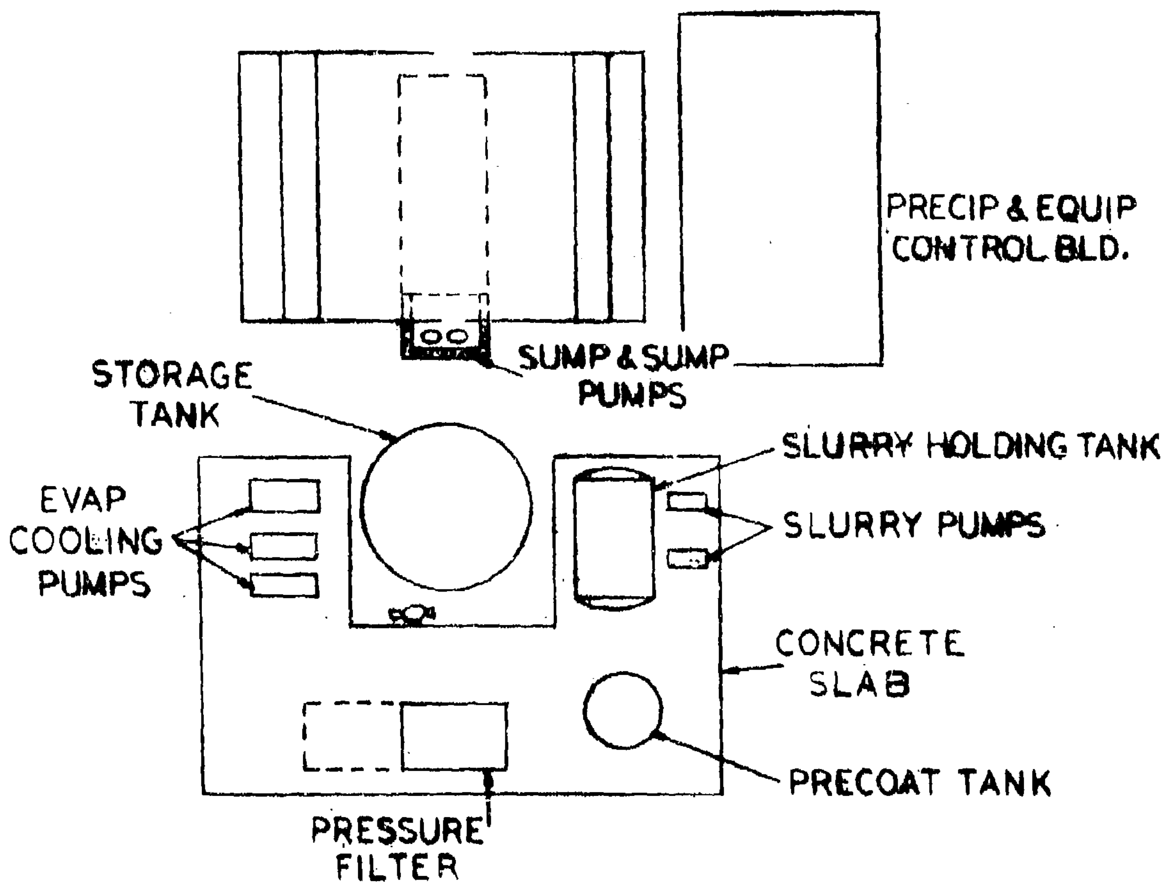
REV. NO.	DATE	DESCRIPTION	ENGR.	SUP.ENG.
		FIRST ISSUE		



PRECIPITATOR EVALUATION

FIGURE 5.3

GENERAL EQUIPMENT ARRANGEMENT

united engineers & constructors inc.

SECTION 6

APPENDIX

A-1 Performance Evaluation Conducted on a Two-Stage Electro-Cell Unit, Jet Engine Test Cell, by American Air Filter Co. Inc. 23 May 1975 and 24 July 1975.

A-2 I-O Memorandum: Air Samples from Electrostatic Precipitator; Results of; w/enclosures, Naval Air Rework Facility, NAS Jax - 16 June 1975.

A-3 Basis for Operating Cost Computations

- Parameters for typical engine test cycles
- Precipitator energization
- Evaporative Cooling
- Spray Reclamation
- Precipitator Washing
- Pressure Filter System

A-4 Conversion of test data to emission factors

A-5 Dimensional Drawing of Prototype Two-Stage Precipitator

APPENDIX A-1

Performance Evaluation Conducted on a

Two-Stage Electro-Cell Unit

Jet Engine Test Cell

American Air Filter Co., Inc.

TEST REPORT
Pilot Two Stage Precipitator
United Engineers and Constructors Inc.
Purchase Order No. BOS-287
NAVFAC Contract N62467-74-C-0161
NARF Jacksonville, Florida

CONTENTS

PEP #702
23 May 1975

Performance Evaluation
Conducted on a Two-Stage Electro-Cell Unit
Jet Engine Test Cell
Naval Air Station
Naval Air Rework Facility
Jacksonville, Florida

6-5

SCOPE:

During the weeks of April 6 and April 13, 1975, a field trip was made to the Naval Air Station located in Jacksonville, Florida. The purpose of this trip was to accomplish performance testing on a two-stage Electro-Cell unit installed on the exhaust system of a jet test cell facility. The tests were conducted in order to establish the unit's efficiency at various flow rates. Based on the results of these tests, an optimum flow rate, which would provide approximately 90% efficiency on the exhaust fume, may be determined.

BACKGROUND:

In operation, the jet test cell is utilized as a permanent stand for testing rebuilt and repaired jet engines, the exhaust of which is emitted to the atmosphere after passing a wet scrubber unit. In search of a better cleaning device, the double unit Electro-Cell test system was installed at this site and positioned such that a portion of the exhaust could be drawn from the main scrubber stack prior to actual scrubber entry (see Illustration A).

ELECTRO-CELL SETUP & PREPARATION:

The Electro-Cell test unit consisted of two (2) ECU-5 units with washers, arranged in series (no fan). An SG-7 power pack was used for each ECU. Ionizer voltage on both packs was set at 13.5 kV. Plate voltage was 6.3 kV. Current draw to the two packs during tests was extremely high due to excessive arcing (see below). Readings would fluctuate from 4 to 8 amps for both packs (2 to 4 amps each). Each washer was controlled by a separate standard arrangement II washer control with detergent option.

The test duct originated with a one foot by one foot duct inlet, located about 10 feet downstream and directly in line with the J-79 jet engine exhaust and cooling water spray rings. Air flow through the unit was regulated by use of various size slotted plates over this inlet.

Initial tests using a damper located downstream of the ECU's for air flow adjustment resulted in severe damage to the rather old test duct. This was due to the tremendous thrust (or velocity pressure) from the engine which built up in the scrubber base section where the sample duct inlet was located.

In addition, extreme arcing in the Electro-Cell elements caused reliability problems with the power packs. This problem was a result of the extremely high entrained moisture content and saturated condition of the test air. Water flow from the sump of the test duct upstream of the test unit was in the magnitude of 15 liters per minute from about 7000 CFM of air. Approximate water flow from the ECU unit drain was 1 liter per minute.

The only deviation from the standard ECU was in the use of silicone insulated high voltage wiring from the power packs to the buss bars. Insulation on the standard wiring was burned off at the buss bar end due to the wet, dirty condition causing arc paths along the outside of the insulated wire to ground.

The location of the test duct inlet, directly in the jet engine exhaust stream, will require, for reliable operation, some sort of weather louvre or other entrained water eliminator arrangement. Permanent installations must be designed to eliminate entrained moisture for reliable operation of the Electro-Cell.

REQUIRED TESTS & EQUIPMENT:

Tests to be performed by AAF personnel were:

A. Determine air flow volumes at various pressure drops across the venturi section, installed upstream of the Electro-Cell banks.

B. Determine the Electro-Cell efficiencies at various flow rates.

Regulation and measurement of air volumes were accomplished by utilization of inlet blank-off plates and pitot tube traverses in the venturi inlet duct rather than using the venturi pressure drops. This method provided a more precise means of determining the actual flow since the venturi pressure "bounced" continuously, creating a problem of accurately depicting the true pressure drop.

Efficiency evaluations were obtained using inlet and outlet dust grain loads determined from AAF five-inch dust sampling equipment. These samplers are designed for capture and measurement of the particulate content in a gas stream and are not intended for any gas analysis. The unit consists of a probe of sufficient length on which various size tips can be installed. The probe in turn is attached to the sampler header which houses the filtering media and monitoring orifice. This header is enclosed

in a Glass-Col heating mantel with appropriate temperature monitors and controls. The header is then attached to a sufficient vacuum source to provide air movement. By correlation of probe tip sizes and orifice pressure regulation iso-kinetic sampling conditions can be established and maintained.

Filtering media employed for these tests is defined as H-93 super-fine glass with initial capability of 99.97% retention of 0.3 micron particles. Retention ability rises as media load increases.

TEST PARAMETERS & RESULTS:

A. Air Flow

Establishment of system air flows was an essential portion of the test program, since sampling rates and operational functions of dust sampling equipment is directly related to these flows. The initial intent was to utilize a venturi (calibrated) for air flow measurement, however, as previously indicated, this approach failed to provide the desired degree of accuracy. The method employed consisted of utilizing four sizes of inlet blank-off plates at the entrance duct to the Electro-Cell unit. Approximately six feet downstream of the inlet and immediately prior to venturi entry, a pitot tube traverse was conducted for each of the four inlet plates. Each traverse consisted of sixteen (16) check points taken in the center of three-inch squares, having divided the one square foot duct into sixteen individual squares. The velocity pressures at each point were obtained and recorded along with temperature and barometric pressures. From these traverses, the total air volumes were calculated as indicated in Table #2, followed by actual calculation and computer data. The results of these traverses were as follows:

1) 12 square inch opening inlet plate provided 2517.6 actual cubic feet per minute.
2) 18 square inch opening inlet plate provided 3827.6 actual cubic feet per minute.
3) 24 square inch opening inlet plate provided 4732.0 actual cubic feet per minute.
4) 36 square inch opening inlet plate provided 7334.1 actual cubic feet per minute.

Using then, an entry area to the Electro-Cell unit of 14.63 square feet, these values provide cell velocities of 172.1, 261.6, 323.4, and 501.3 feet per minute, respectively.

B. Dust Sampling & Efficiencies

Having established total system flows, a series of upstream and downstream dust loading samples were obtained using the AAF 5-inch sampling devices. Since velocity pressures are incorporated in the formulation of iso-kinetic sampling rates, it was necessary to derive the velocity pressure by calculation rather than direct measurement due to the low pressure values. From Table 1, it will be noted that duct flow in feet per minute is indicated for each of the four inlet plates employed. (Duct area was 10 square feet.)

Using these volumes, we are able to calculate the average velocity pressure in the duct by means of

$$V_p = \frac{\text{Velocity (FPM)}}{4005}$$

where V_p is the velocity pressure, v = velocity in feet per minute, and 4005 the constant. Having derived the velocity pressure values, sampling rates were determined for upstream and downstream units incorporating various sized inlet tips. However, since the velocity pressure values are the average at the particular system volumes, it was determined that sampling rates slightly larger than iso-kinetic should be used during sampler runs to insure that sufficient sampling was accomplished. This will not affect the results of the loading tests since each cubic foot of air contains a volume of dust consisting basically of 0 - 5 micron material which has negligible gravitational and inertial forces acting upon it, due to the minute size. This volume vs. air sampled provides the actual dust loading in grains per cubic foot.

The individual tests, consisting of upstream and downstream sampling, conducted simultaneously, were performed at various unit flow as illustrated in Table 1. As will be noted from this Table, the inlet grain loadings ranged from 0.00120 to 0.00290 grains per cubic foot of air and the outlet grain loadings varied from 0.0005 to 0.0001 grains per cubic foot. The efficiency band with both Electro-Cell units energized varied from 82.75% to 97.64%.

Compiling the results of the total test program, it was established that the actual flow rate at which the two-stage Electro-Cell would provide approximately 90% efficiency was 501 FPM cell velocity with the total system flow at 7334.0 CFM. Also one test was conducted with only one bank of Electro-Cells energized and the test conducted at these conditions provided an 80% collection efficiency.

A summary of all tests is illustrated in Tables 1, 2, and 3, followed by actual test data and computer printouts.

Richard P. Williams

Richard P. Williams

Wilson Welch

Wilson Welch

ws: 19 MAY 1975

ATTACHMENTS

cc: PEP#662
K. Westlin
H. McShane
J. Ashe
Orig. - PEP #702

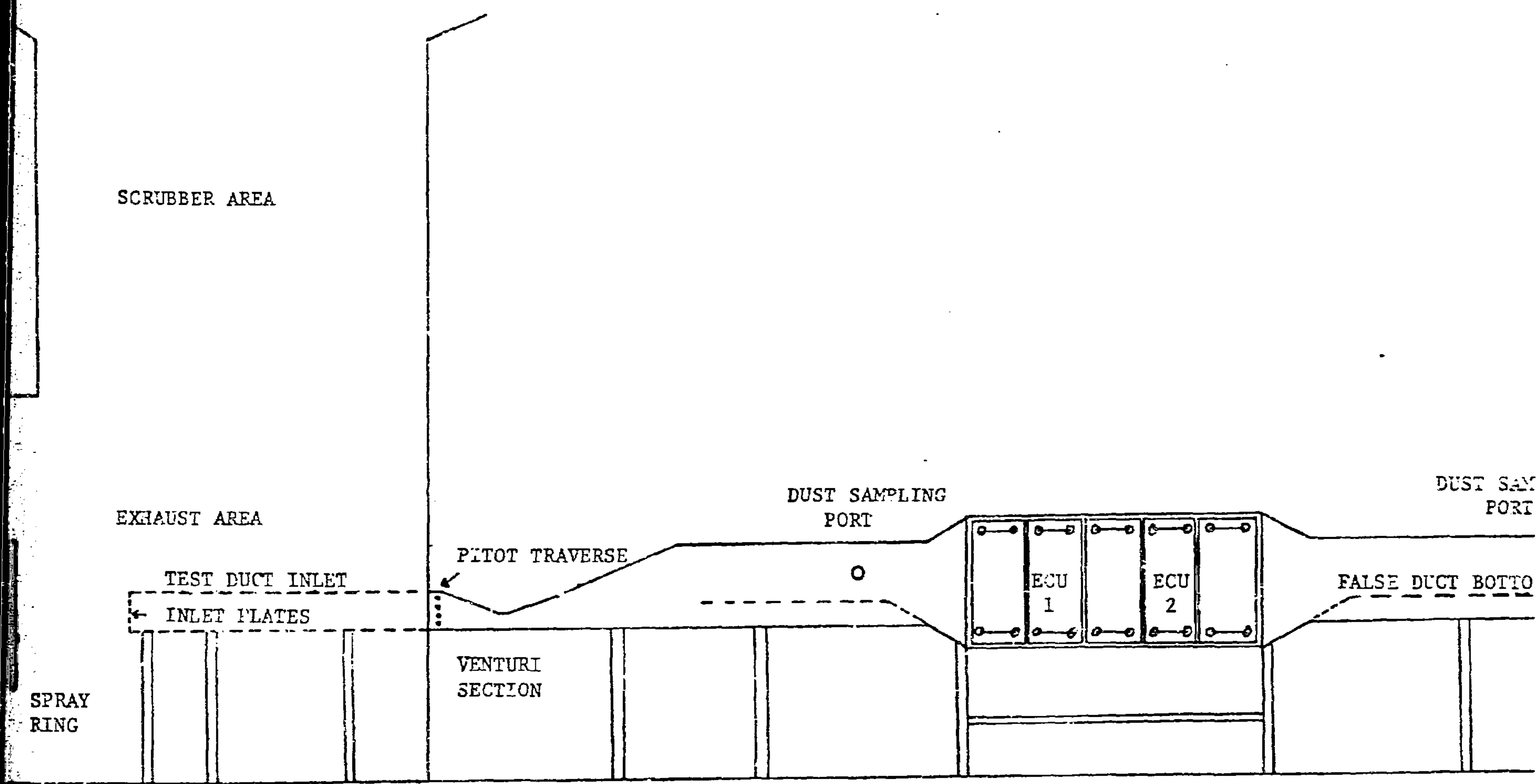


ILLUSTRATION A. Test System Installation (Not to Scale)

TABLE 1
OPERATIONAL PARAMETERS & TEST RESULTS SUMMARY* FOR AAF TWIN
ELECTRO-CELL UNIT AND TEST ENGINE J-79-10, SERIAL #433544

DATE OF TEST	4/7/75	4/8/75	4/9/75	4/9/75	4/10/75	4/10/75	4/10/75	4/11/75	4/11/75	4/14/75	4/14/75	4/15/75
TEST NUMBER	V-1	V-2	P-1	P-2	V-3	P-3	V-4	P-4	P-5	P-6	P-7	P-8(1)
ACTUAL TEST TIME	02:30	12:25	08:40 09.32	13:50 14:50	10:15	11:30 12:30	15:57	14:40 16:10	17:00 18:30	11:00 12:30	15:00 16:00	15:15 16:15
ORIFICE SIZE (IN^2)	36	12	12	12	18	18	24	24	24	36	36	36
ENGINE RPM (AVG)	7000	7000	7500	7000	7000	7000	6974	7000	6998	7003	6996	7000
THRUST (AVG)	7310	7340	7500	7220	7400	7345	7040	7325	7160	7373	7138	7319
FUEL FLOW (AVG)	6048	6044	6180	5983	6194	6060	5831	6060	5924	6071	7132	5877
E.G.T. (AVG)	994	989	992	988	1004	990	975	998	985	987	987	941
AMBIENT TEMPERATURE F°	73	73	68-71	73-75	71	70	74	73	75	71.5	76	73
INLET DUCT TEMPERATURE F°	131	127	130-132	130-133	131-133	128-132	131-133	131-133	131-133	131-132	131-133	128-132
BAROMETRIC PRESSURE IN Hg	30.07	30.06	30.10	30.05	29.98	29.95	29.88	29.75	29.77	30.13	29.98	29.98
TOTAL AIR VOLUME (IN CFM)	7334.1	2517.6	2517.6	2517.6	3827.6	3827.6	4732.0	4732.0	4732.0	7334.1	7334.1	7334.1
DUCT VELOCITY (IN FPM)	733.4	251.7	251.7	251.7	382.7	382.7	473.2	473.2	473.2	733.4	733.4	733.4
CELL VELOCITY (IN FPM)	501.4	172.1	172.1	172.1	261.6	261.6	323.4	323.4	323.4	501.3	501.3	501.3
INLET CONCENTRATION Gr./Cu.Ft.	-	-	0.00290	0.00120	-	0.00121	-	0.00194	.00192	0.00270	0.00270	.0015356
OUTLET CONCENTRATION	-	-	0.0005	0.0001465	-	0.0000401	-	0.00001465	.00010	0.0002165	0.0003	0.0003058
SYSTEM EFFICIENCY, %	-	-	82.75	87.79	-	96.68	-	97.64	94.79	91.98	88.88	80.08

(1)System operating with only one set of Electro-Cells energized.
*Actual data and computer prints given in Section A.

TABLE 2
Pitot Tube Velocity Traverse Summary
on Venturi Inlet

DATE	4/7/75	4/8/75	4/10/75	4/11/75
TEST NO.	V-1	V-2	V-3	V-4
ORIFICE SIZE (IN^2)	36	12	18	24
BAROMETRIC PRESSURE ABSOLUTE	30.07	30.07	29.98	29.88
DRY BULB TEMPERATURE	130.0	127.0	130.0	130.0
WET BULB TEMPERATURE	130.0	127.0	130.0	130.0
DENSITY - lbs/ft^3	0.06377	0.06440	0.06357	0.06334
PITOT TUBE CORR. FACTOR	1.0	1.0	1.0	1.0
INLET SIZE (FT^2)	1.0	1.0	1.0	1.0
NO. OF POINTS	16	16	16	16
ACFM*	7334.1	2517.6	3827.6	4732.0
SCFM*	6236.1	2161.8	3244.3	3996.6

*Calculation formulas described on following page.

TABLE 3

5-INCH SAMPLE TEST RESULTS

Date	Test No. & Position	Pad No.	Pad Gain Grams	Test Duration Minutes	QSSUM	QDSUM	QDASUM	CONC/ACF	CONC/DGSCF	CONC/DUC ACF
4/9/75	1-Upstream	V-839	0.0189	52	100.8518	64.8744	84.4977	0.0029	0.0045	0.0035
	1-Downstream	V-840	0.0041	52	116.2136	75.4516	97.8994	0.0005	0.0008	0.0006
4/9/75	2-Upstream	CT-518	0.0086	60	115.2485	74.9531	97.8162	0.0012	0.0018	0.001465
	2-Downstream	CT-519	0.0017	60	180.3103	118.6034	154.2770	0.0001	0.0002	0.0002
4/10/75	3-Upstream	CT-521	0.0136	60	174.9916	111.4972	147.4464	0.00121	0.0019	0.0014
	3-Downstream	CT-520	0.0007	60	271.3594	176.1802	235.4408	0.0000401	0.0001	0.00005
4/11/75	4-Upstream	CT-523	0.0407	90	326.5924	205.6521	274.9590	.00194	0.0031	0.0023
	4-Downstream	CT-522	0.0015	90	511.6152	330.2221	444.2592	.0000456	0.0001	0.00005
4/11/75	5-Upstream	CT-525	0.0400	90	324.6415	206.8295	276.5499	0.00192	0.0030	0.0022
	5-Downstream	CT-524	0.0032	90	514.0999	328.3407	441.8598	0.0001	0.0002	0.0001
4/14/75	6-Upstream	CT-531	0.0543	90	315.6220	203.7582	268.5752	0.00270	0.0041	0.0031
	6-Downstream	CT-530	0.0071	90	506.4850	320.8162	429.1876	0.0002165	0.0003	0.0003
4/14/75	7-Upstream	CT-529	0.0376	60	211.0631	134.9075	180.0978	0.00270	0.0043	0.0032
	7-Downstream	CT-528	0.0062	60	337.4626	213.9625	287.7871	0.0003	0.0004	0.0003
4/15/75	8-Upstream	CT-527	0.0208	60	209.4048	136.9256	180.2832	0.0015356	0.0023	0.0018
	8-Downstream	CT-526	0.0066	60	334.9960	217.1509	287.8173	0.0003058	0.0005	0.0004

QSSUM = total actual sampled volume at sampler temp. and press., ACF.

QDSUM = total dry gas sampled volume at 70 degrees F and 29.92 in HG.

QDASUM = total actual sampled volume at duct temperature and pressure.

CONC/ACF = grains per cubic foot at sampler conditions, gr/ACF.

CONC/DGSCF = grains per cubic foot of dry gas at 70 degrees F and 29.92 in HG.

CONC/DUCT ACF = grains per cubic foot at duct conditions, gr/duct ACF.

Calculation of Air Volume from Pitot Traverse
Computer Program 7058

Air Calculations (gas option = 1)

$$DENS = \frac{P - .38\ (PSAT - P(DB - WB)/2700}{.754\ (DB + 459.6)}$$ (From AMCA Standard Test Code Bulletin 210 Section IV)

P = Duct Pressure in in. Hg = PB - PD

PB = Barometric Pressure in in. Hg

PD = Duct Pressure depression in in. Hg

DB, WB = Duct Temperatures in ^{o}F

P_{SAT} = Saturation Temperature at WB in in. Hg

$$ACFM = 1096.5\ A\ \left(\frac{\Sigma}{N}\ \frac{\sqrt{VP}}{\sqrt{DENS}}\right)$$

A = Duct Area in ft^2

VP = Corrected pitot velocity pressure in in. WG

N = Number of traverse points of VP

$$SCFM = ACFM\ \left(\frac{DENS}{.075}\right)$$

$$DGCFM = ACFM\ \left(\frac{70 + 459.67}{DB + 459.67}\right)\left(\frac{P - PV}{29.92}\right)$$

$$PV = \left(PSAT' - \frac{.3895\ P'\ (DB - WB)}{1093.8 - .576 \times WB}\right)(2.036) \text{ in in. Hg}$$

P_{SAT}' and P' in psia

DUCT AREA CODE = 3 CORRECTION CODE = 1

GAS CODE = 1 BAROMETER ABS = 30.07000

DRY BULB TEMP = 130.00000 WET BULB TEMP = 130.00000

LENGTH = 12.00000 WIDTH = 12.00000

PITOT CORRECTION FACTOR = 1.00000

NO. OF POINTS = 16

POSITION	VELOCITY PRESSURE
1	2.500
2	2.500
3	2.750
4	2.750
5	3.000
6	3.000
7	3.000
8	3.000
9	3.000
10	3.000
11	2.900
12	3.100
13	2.600
14	2.700
15	2.900
16	3.000

RM = 1.6890898 DAREA = 1.000 SQ FT

DENS = 0.06377 ACFM = 7334.1

SCFM = 6236.1

FORM C7058 MAVFAC INLET TO VENTURI AIR VOLUME TEST 2 8APR75 PAGE 1
04/21/75 10:34

DUCT AREA CODE = 3

CORRECTION CODE = 1

GAS CODE = 1

BAROMETER ABS = 30.07000

DRY BULB TEMP = 127.00000

WET BULB TEMP = 127.00000

LENGTH = 12.00000

WIDTH = 12.00000

PITOT CORRECTION FACTOR = 1.00000

NO. OF POINTS = 16

POSITION	VELOCITY PRESSURE
11	0.240
12	0.320
13	0.300
14	0.280
21	0.320
22	0.450
23	0.350
24	0.340
31	0.350
32	0.350
33	0.350
34	0.360
41	0.300
42	0.350
43	0.400
44	0.400

RM = 0.5826707

DAREA = 1.000 SQ FT

DENS = 0.06440

ACFM = 2517.6

SCFM = 2161.8

04/21/75 10:19

DUCT AREA CODE = 3 CORRECTION CODE = 1

GAS CODE = 1 BAROMETER ABS = 29.98000

DRY BULB TEMP = 130.00000 WET BULB TEMP = 130.00000

LENGTH = 12.00000 WIDTH = 12.00000

PITOT CORRECTION FACTOR = 1.00000

NO. OF POINTS = 16

POSITION	VELOCITY PRESSURE
11	0.650
12	0.550
13	0.700
14	0.680
21	0.750
22	0.800
23	0.750
24	0.800
31	0.850
32	0.950
33	1.000
34	0.900
41	0.850
42	0.900
43	0.800
44	0.550

RM = 0.8801271 DAREA = 1.000 SQ FT

DENS = 0.06357 ACFM = 3827.6

SCFM = 3244.3

04/21/75 10:19

DUCT AREA CODE = 3 CORRECTION CODE = 1

GAS CODE = 1 BAROMETER ABS = 29.88000

DRY BULB TEMP = 130.00000 WET BULB TEMP = 130.00000

LENGTH = 12.00000 WIDTH = 12.00000

PITOT CORRECTION FACTOR = 1.00000

NO. OF POINTS = 16

POSITION	VELOCITY PRESSURE
11	1.000
12	0.800
13	1.200
14	1.100
21	1.250
22	1.300
23	1.250
24	1.250
31	1.300
32	1.350
33	1.350
34	1.300
41	1.050
42	1.200
43	1.150
44	1.100

RM = 1.0861518 DAREA = 1.000 SQ FT

DENS = 0.06334 ACFM = 4732.0

SCFM = 3996.6

FORM C7040 NAVFAC JET DUST SAMPLER TEST 1 UPSTREAM 9APR75 PAGE 1
04/21/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 V-839
PAD2

TOTAL FINAL PAD(S) WEIGHT	2.00080 GRAMS
TOTAL INITIAL PAD(S) WEIGHT	1.98190 GRAMS
TOTAL PAD(S) WEIGHT GAIN	0.01890 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 30.100 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 1 UPSTREAM 9 APR75 PAGE 2
04/21/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	130.	130.	250.	1.67	137.9	30.100	4.526	0.0532
5.00	7.00	130.	130.	240.	1.66	137.3	30.100	4.526	0.0539
7.00	10.00	130.	130.	230.	1.65	136.7	30.100	4.526	0.0547
10.00	15.00	130.	130.	230.	1.65	136.2	30.100	4.526	0.0547
15.00	20.00	130.	130.	240.	1.66	137.3	30.100	4.526	0.0539
20.00	25.00	130.	130.	245.	1.67	137.6	30.100	4.526	0.0536
25.00	30.00	130.	130.	245.	1.67	137.6	30.100	4.526	0.0536
30.00	35.00	130.	130.	250.	1.67	137.9	30.100	4.526	0.0532
35.00	40.00	130.	130.	250.	1.67	137.9	30.100	4.526	0.0532
40.00	45.00	130.	130.	250.	1.67	137.9	30.100	4.526	0.0532
45.00	50.00	130.	130.	245.	1.67	137.6	30.100	4.526	0.0536
50.00	52.00	130.	130.	250.	1.67	137.9	30.100	4.526	0.0532

FORM C7040 NAVFAC JET DUST SAMPLER TEST 1 UPSTREAM 9 APR75 PAGE 3
04/21/75

QSSUM = 100.8518 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 64.8744 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 84.4977 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0189 GRAMS

CONC/ACF = 0.0029 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0045 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

CONC/DUCT ACF = 0.0035 GRAINS PER CUBIC FOOT AT DUCT CONDITIONS, GR/DUCT ACF

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 V-840
PAD2

TOTAL FINAL PAD(S) WEIGHT 1.97860 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 1.97450 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00410 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 30.100 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	2.00	128.	128.	225.	4.20	134.8	30.100	4.290	0.0553
2.00	7.00	128.	128.	225.	2.20	134.8	30.100	4.290	0.0553
7.00	10.00	128.	128.	225.	2.20	134.8	30.100	4.290	0.0553
10.00	15.00	128.	128.	236.	2.17	135.5	30.100	4.290	0.0544
15.00	20.00	130.	130.	255.	2.12	138.2	30.100	4.526	0.0528
20.00	25.00	130.	130.	245.	2.14	137.6	30.100	4.526	0.0536
25.00	30.00	130.	130.	245.	2.14	137.6	30.100	4.526	0.0536
30.00	35.00	130.	130.	250.	2.16	137.9	30.100	4.526	0.0532
35.00	40.00	130.	130.	240.	2.19	137.3	30.100	4.526	0.0539
40.00	45.00	130.	130.	245.	2.14	137.6	30.100	4.526	0.0536
45.00	50.00	130.	130.	235.	2.17	137.0	30.100	4.526	0.0543
50.00	52.00	130.	130.	235.	2.17	137.0	30.100	4.526	0.0543

QSSUM = 116.2136 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 75.4516 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 97.8994 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0041 GRAMS

GR/ACF = 0.0005 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

GR/DSCF = 0.0003 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

GR/DUCT ACF = 0.0006 GRAINS PER CUBIC FOOT AT DUCT CONDITIONS, GR/DUCT ACF

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-518
PAD2

TOTAL FINAL PAD(S) WEIGHT	2.08120	GRAMS
TOTAL INITIAL PAD(S) WEIGHT	2.07260	GRAMS
TOTAL PAD(S) WEIGHT GAIN	0.00860	GRAMS

BAROMETRIC PRESSURE ABSOLUTE 30.050 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	1.00	130.	130.	250.	1.66	137.9	30.050	4.526	0.0531
1.00	3.00	130.	130.	245.	1.66	137.6	30.050	4.526	0.0535
3.00	5.00	130.	130.	240.	1.66	137.3	30.050	4.526	0.0538
5.00	8.00	130.	130.	230.	1.65	136.7	30.050	4.526	0.0546
8.00	10.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542
10.00	15.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542
15.00	20.00	130.	130.	240.	1.66	137.3	30.050	4.526	0.0538
20.00	30.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542
30.00	35.00	130.	130.	230.	1.65	136.7	30.050	4.526	0.0546
35.00	40.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542
40.00	45.00	130.	130.	230.	1.65	136.7	30.050	4.526	0.0546
45.00	50.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542
50.00	55.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542
55.00	60.00	130.	130.	235.	1.65	137.0	30.050	4.526	0.0542

QSSUM = 115.2485 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 74.9531 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 97.8162 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0086 GRAMS

[illegible] = 0.0012 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

[illegible]CF = 0.0018 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 2 DOWNSTREAM 9 APR75 PAGE 4
04/21/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

RAD1 CT-519
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.03620 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.03450 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00170 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 30.050 IN.HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 2 DOWNSTREAM 9 APR75 PAGE 5
04/21/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	120.	120.	250.	4.20	130.6	30.050	3.446	0.0538
5.00	9.00	130.	130.	235.	4.12	137.0	30.050	4.526	0.0542
9.00	15.00	130.	130.	240.	4.15	137.3	30.050	4.526	0.0538
15.00	20.00	130.	130.	210.	3.98	135.5	30.050	4.526	0.0552
20.00	25.00	130.	130.	225.	4.06	136.4	30.050	4.526	0.0550
25.00	30.00	130.	130.	225.	4.06	136.4	30.050	4.526	0.0550
30.00	35.00	130.	130.	220.	4.02	136.1	30.050	4.526	0.0554
35.00	40.00	130.	130.	230.	4.09	136.7	30.050	4.526	0.0546
40.00	45.00	130.	130.	225.	4.06	136.4	30.050	4.526	0.0550
45.00	50.00	130.	130.	225.	4.06	136.4	30.050	4.526	0.0550
50.00	55.00	131.	131.	230.	4.09	137.5	30.050	4.648	0.0545
55.00	60.00	132.	132.	230.	4.09	138.3	30.050	4.773	0.0544

FORM C7040 NAVFAC JET DUST SAMPLER TEST 2 DOWNSTREAM 9 APR75 PAGE 6
04/21/75

QSSUM = 130.3103 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 113.6034 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 154.2770 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0017 GRAMS

CONC/ACF = 0.0001 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0002 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-521
PAD2

TOTAL FINAL PAD(S) WEIGHT 1.99680 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 1.98320 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.01360 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.950 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	DPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	2.00	130.	130.	245.	3.75	137.6	29.950	4.526	0.0533
2.00	5.00	130.	130.	240.	3.75	137.3	29.950	4.526	0.0537
5.00	10.00	130.	130.	235.	3.75	137.0	29.950	4.526	0.0540
10.00	15.00	130.	130.	240.	3.75	137.3	29.950	4.526	0.0537
15.00	20.00	131.	131.	245.	3.75	138.3	29.950	4.648	0.0532
20.00	25.00	132.	132.	240.	3.75	138.8	29.950	4.773	0.0535
25.00	30.00	132.	132.	240.	3.75	138.8	29.950	4.773	0.0535
30.00	35.00	132.	132.	240.	3.75	138.8	29.950	4.773	0.0535
35.00	40.00	132.	132.	240.	3.75	138.8	29.950	4.773	0.0535
40.00	45.00	132.	132.	245.	3.75	139.1	29.950	4.773	0.0531
45.00	50.00	132.	132.	245.	3.75	139.1	29.950	4.773	0.0531
50.00	55.00	132.	132.	245.	3.75	139.1	29.950	4.773	0.0531
55.00	60.00	132.	132.	245.	3.75	139.1	29.950	4.773	0.0531

QSSUM = 174.9916 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 111.4972 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 147.4464 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0136 GRAMS

CONC/ACF = 0.0012 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DSCF = 0.0019 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-520
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.01270 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.01200 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00070 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.950 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	125.	125.	250.	9.58	134.1	29.950	3.955	0.0530
5.00	10.00	132.	132.	210.	9.07	137.1	29.950	4.773	0.0558
10.00	15.00	133.	133.	210.	9.07	137.9	29.950	4.901	0.0557
15.00	20.00	135.	135.	220.	9.17	140.1	29.950	5.166	0.0547
20.00	25.00	133.	133.	220.	9.17	138.5	29.950	4.901	0.0549
25.00	30.00	135.	135.	220.	9.17	140.1	29.950	5.166	0.0547
30.00	35.00	135.	135.	225.	9.26	140.4	29.950	5.166	0.0543
35.00	40.00	135.	135.	225.	9.26	140.4	29.950	5.166	0.0543
40.00	45.00	133.	133.	225.	9.26	138.8	29.950	4.901	0.0545
45.00	50.00	133.	133.	225.	9.26	138.8	29.950	4.901	0.0545
50.00	55.00	133.	133.	225.	9.26	138.8	29.950	4.901	0.0545
55.00	60.00	133.	133.	225.	9.26	138.8	29.950	4.901	0.0545

QSSUM = 271.3594 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 176.1802 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 235.4408 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0007 GRAMS

CONC/ACF = 0.0000 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DSCF = 0.0001 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 4 UPSTREAM 11APR75   PAGE 1
04/22/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A   ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-523
PAD2

TOTAL FINAL PAD(S) WEIGHT   2.00180 GRAMS
TOTAL INITIAL PAD(S) WEIGHT   1.96110 GRAMS
TOTAL PAD(S) WEIGHT GAIN   0.04070 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.740 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 4 UPSTREAM 11APR75   PAGE 2
04/22/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	130.	130.	245.	5.75	137.5	29.740	4.526	0.0529
5.00	8.00	131.	131.	240.	5.75	138.0	29.740	4.648	0.0532
8.00	12.00	131.	131.	225.	5.75	137.1	29.740	4.648	0.0543
12.00	15.00	132.	132.	230.	5.75	138.2	29.740	4.773	0.0538
15.00	20.00	132.	132.	240.	5.75	138.8	29.740	4.773	0.0531
20.00	35.00	132.	132.	245.	5.75	139.0	29.740	4.773	0.0527
35.00	45.00	132.	132.	245.	5.75	139.0	29.740	4.773	0.0527
45.00	60.00	132.	132.	245.	5.75	139.0	29.740	4.773	0.0527
60.00	65.00	132.	132.	250.	5.75	139.3	29.740	4.773	0.0523
65.00	70.00	132.	132.	240.	5.75	138.8	29.740	4.773	0.0531
70.00	85.00	132.	132.	245.	5.75	139.0	29.740	4.773	0.0527
85.00	90.00	132.	132.	240.	5.75	138.8	29.740	4.773	0.0531

FORM C7040 NAVFAC JET DUST SAMPLER TEST 4 UPSTREAM 11APR75   PAGE 3
04/22/75

QSSUM = 326.5924 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 203.6521 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 274.9590 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN =   0.0407 GRAMS

CONC/ACF   = 0.0019 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0031 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-522
PAD2

TOTAL FINAL PAD(S) WEIGHT 1.97430 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 1.97280 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00150 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.740 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	130.	130.	230.	14.50	136.6	29.740	4.526	0.0540
5.00	10.00	132.	132.	200.	14.50	136.4	29.740	4.773	0.0562
10.00	15.00	132.	132.	200.	14.50	136.4	29.740	4.773	0.0562
15.00	20.00	133.	133.	210.	14.50	137.8	29.740	4.901	0.0553
20.00	25.00	133.	133.	210.	14.50	137.8	29.740	4.901	0.0553
25.00	30.00	133.	133.	220.	14.50	138.4	29.740	4.901	0.0545
30.00	35.00	133.	133.	215.	14.50	138.1	29.740	4.901	0.0549
35.00	40.00	133.	133.	225.	14.50	138.7	29.740	4.901	0.0541
40.00	45.00	133.	133.	230.	14.50	139.0	29.740	4.901	0.0537
45.00	50.00	133.	133.	225.	14.50	138.7	29.740	4.901	0.0541
50.00	55.00	133.	133.	228.	14.50	138.9	29.740	4.901	0.0539
55.00	60.00	133.	133.	235.	14.50	139.3	29.740	4.901	0.0534
60.00	65.00	133.	133.	232.	14.50	139.1	29.740	4.901	0.0536
65.00	70.00	133.	133.	230.	14.50	139.0	29.740	4.901	0.0537
70.00	75.00	133.	133.	225.	14.50	138.7	29.740	4.901	0.0541
75.00	80.00	133.	133.	230.	14.50	139.0	29.740	4.901	0.0537
80.00	85.00	133.	133.	230.	14.50	139.0	29.740	4.901	0.0537
85.00	90.00	133.	133.	232.	14.50	139.1	29.740	4.901	0.0536

QSSUM = 511.6152 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 330.2321 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 444.2592 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-525
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.08480 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.04480 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.04000 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.770 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	3.00	132.	132.	235.	5.75	138.5	29.770	4.773	0.0535
3.00	5.00	132.	132.	230.	5.75	138.2	29.770	4.773	0.0539
5.00	9.00	132.	132.	230.	5.75	138.2	29.770	4.773	0.0539
9.00	19.00	132.	132.	235.	5.75	138.5	29.770	4.773	0.0535
19.00	30.00	132.	132.	230.	5.75	138.2	29.770	4.773	0.0539
30.00	35.00	132.	132.	235.	5.75	138.5	29.770	4.773	0.0535
35.00	40.00	132.	132.	240.	5.75	138.8	29.770	4.773	0.0531
40.00	50.00	132.	132.	235.	5.75	138.5	29.770	4.773	0.0535
50.00	70.00	132.	132.	240.	5.75	138.8	29.770	4.773	0.0531
70.00	75.00	132.	132.	235.	5.75	138.5	29.770	4.773	0.0535
75.00	80.00	132.	132.	230.	5.75	138.2	29.770	4.773	0.0539
80.00	85.00	132.	132.	235.	5.75	138.5	29.770	4.773	0.0535
85.00	90.00	132.	132.	230.	5.75	138.2	29.770	4.773	0.0539

QSSUM = 324.6415 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 206.8295 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 276.5499 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0400 GRAMS

CONC/ACF = 0.0019 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

FORM C7040 NAVFAC JET DUST SAMPLER TEST 5 DOWNSTREAM 11APR75 PAGE 4
04/22/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-524
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.01220 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.00900 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00320 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.770 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 5 DOWNSTREAM 11APR75 PAGE 5
04/22/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	133.	133.	220.	14.50	138.4	29.770	4.901	0.0546
5.00	10.00	133.	133.	220.	14.50	138.4	29.770	4.901	0.0546
10.00	15.00	133.	133.	225.	14.50	138.7	29.770	4.901	0.0542
15.00	20.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
20.00	25.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
25.00	30.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
30.00	35.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
35.00	40.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
40.00	45.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
45.00	50.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
50.00	55.00	133.	133	230.	14.50	139.0	29.770	4.901	0.0538
55.00	60.00	133.	133.	230.	14.50	139.0	29.770	4.901	0.0538
60.00	65.00	133.	133.	232.	14.50	139.1	29.770	4.901	0.0536
65.00	70.00	133.	133.	234.	14.50	139.2	29.770	4.901	0.0535
70.00	75.00	133.	133.	235.	14.50	139.3	29.770	4.901	0.0534
75.00	80.00	133.	133.	235.	14.50	139.3	29.770	4.901	0.0534
80.00	85.00	133.	133.	234.	14.50	139.2	29.770	4.901	0.0535
85.00	90.00	132.	132.	232.	14.50	138.3	29.770	4.773	0.0537

FORM C7040 NAVFAC JET DUST SAMPLER TEST 5 DOWNSTREAM 11APR75 PAGE 6
04/22/75

QSSUM = 514.0999 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 328.3407 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 441.8598 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

FORM C7040 NAVFAC JET DUST SAMPLER TEST 6 UPSTREAM 14APR75 PAGE 1
04/22/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-531
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.00440 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 1.95010 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.05430 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 30.130 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 6 UPSTREAM 14APR75 PAGE 2
04/22/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	2.00	132.	132.	250.	5.50	139.4	30.130	4.773	0.0531
2.00	3.00	132.	132.	245.	5.50	139.1	30.130	4.773	0.0534
3.00	10.00	132.	132.	240.	5.50	138.9	30.130	4.773	0.0538
10.00	11.00	132.	132.	228.	5.40	138.2	30.130	4.773	0.0547
11.00	14.00	132.	132.	235.	5.50	138.6	30.130	4.773	0.0542
14.00	22.00	132.	132.	240.	5.50	138.9	30.130	4.773	0.0539
22.00	25.00	132.	132.	235.	5.50	138.6	30.130	4.773	0.0542
25.00	30.00	132.	132.	230.	5.50	138.3	30.130	4.773	0.0546
30.00	35.00	132.	132.	235.	5.50	138.6	30.130	4.773	0.0542
35.00	45.00	132.	132.	240.	5.50	138.9	30.130	4.773	0.0538
45.00	65.00	132.	132.	235.	5.50	138.6	30.130	4.773	0.0542
65.00	80.00	132.	132.	230.	5.50	138.3	30.130	4.773	0.0546
80.00	90.00	132.	132.	235.	5.50	138.6	30.130	4.773	0.0542

FORM C7040 NAVFAC JET DUST SAMPLER TEST 6 UPSTREAM 14APR75 PAGE 3
04/22/75

QSSUM = 315.6220 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 203.7582 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 268.5752 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0543 GRAMS

CONC/ACF = 0.0027 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0041 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 6 DOWNSTREAM 14APR75   PAGE 1
04/23/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A   ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-530
PAD2

TOTAL FINAL PAD(S) WEIGHT   1.95040 GRAMS
TOTAL INITIAL PAD(S) WEIGHT   1.94330 GRAMS
TOTAL PAD(S) WEIGHT GAIN   0.00710 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 30.130 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 6 DOWNSTREAM 14APR75   PAGE 2
04/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	133.	133.	250.	14.00	140.2	30.130	4.901	0.0530
5.00	10.00	133.	133.	240.	14.00	139.6	30.130	4.901	0.0537
10.00	15.00	134.	134.	240.	14.00	140.4	30.130	5.032	0.0536
15.00	20.00	134.	134.	240.	14.00	140.4	30.130	5.032	0.0536
20.00	25.00	134.	134.	242.	14.00	140.5	30.130	5.032	0.0535
25.00	30.00	134.	134.	242.	14.00	140.5	30.130	5.032	0.0535
30.00	35.00	134.	134.	242.	14.00	140.5	30.130	5.032	0.0535
35.00	40.00	134.	134.	242.	14.00	140.5	30.130	5.032	0.0535
40.00	45.00	134.	134.	240.	14.00	140.4	30.130	5.032	0.0536
45.00	50.00	134.	134.	240.	14.00	140.4	30.130	5.032	0.0536
50.00	55.00	134.	134.	238.	14.00	140.3	30.130	5.032	0.0538
55.00	60.00	135.	135.	238.	14.00	141.1	30.130	5.166	0.0537
60.00	65.00	135.	135.	240.	14.00	141.2	30.130	5.166	0.0535
65.00	70.00	135.	135.	240.	14.00	141.2	30.130	5.166	0.0535
70.00	75.00	134.	134.	240.	14.00	140.4	30.130	5.032	0.0536
75.00	80.00	134.	134.	242.	14.00	140.5	30.130	5.032	0.0535
80.00	85.00	135.	135.	242.	14.00	141.3	30.130	5.166	0.0534
85.00	90.00	135.	135.	242.	14.00	141.3	30.130	5.166	0.0534

FORM C7040 NAVFAC JET DUST SAMPLER TEST 6 DOWNSTREAM 14APR75   PAGE 3
04/23/75

QSSUM = 506.4850 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 320.8162 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 429.1876 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

FORM C7040 NAVFAC JET DUST SAMPLER TEST 7 UPSTREAM 14APR75 PAGE 1
04/23/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-529
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.02410 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 1.98650 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.03760 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.980 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 7 UPSTREAM 14APR75 PAGE 2
04/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	1.00	133.	133.	250.	5.50	140.2	29.980	4.901	0.0527
1.00	3.00	133.	133.	240.	5.50	139.6	29.980	4.901	0.0534
3.00	6.00	133.	133.	235.	5.50	139.3	29.980	4.901	0.0538
6.00	9.00	133.	133.	230.	5.50	139.0	29.980	4.901	0.0542
9.00	15.00	133.	133.	225.	5.50	138.8	29.980	4.901	0.0546
15.00	22.00	133.	133.	230.	5.50	139.0	29.980	4.901	0.0542
22.00	25.00	133.	133.	225.	5.50	138.8	29.980	4.901	0.0546
25.00	30.00	133.	133.	230.	5.50	139.0	29.980	4.901	0.0542
30.00	52.00	133.	133.	240.	5.50	139.6	29.980	4.901	0.0534
52.00	55.00	133.	133.	235.	5.50	139.3	29.980	4.901	0.0538
55.00	60.00	133.	133.	240.	5.50	139.6	29.980	4.901	0.0534

FORM C7040 NAVFAC JET DUST SAMPLER TEST 7 UPSTREAM 14APR75 PAGE 3
04/23/75

QSSUM = 211.0631 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 134.9075 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 180.0978 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0376 GRAMS

CONC/ACF = 0.0027 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0043 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

CONC/DUCT ACF = 0.0032 GRAINS PER CUBIC FOOT AT DUCT CONDITIONS, GR/DUCT ACF

FORM C7040 NAVFAC JET DUST SAMPLER TEST 7 DOWNSTREAM 14APR75 PAGE 4
04/23/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-528
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.01680 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.01060 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00620 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.980 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 7 DOWNSTREAM 14APR75 PAGE 5
04/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	134.	134.	270.	14.00	142.0	29.980	5.032	0.0512
5.00	10.00	134.	134.	220.	14.00	139.3	29.980	5.032	0.0549
10.00	15.00	134.	134.	220.	14.00	139.3	29.980	5.032	0.0549
15.00	20.00	134.	134.	230.	14.00	139.8	29.980	5.032	0.0541
20.00	25.00	134.	134.	235.	14.00	140.1	29.980	5.032	0.0537
25.00	30.00	135.	135.	235.	14.00	140.9	29.980	5.166	0.0536
30.00	35.00	134.	134.	235.	14.00	140.1	29.980	5.032	0.0537
35.00	40.00	134.	134.	240.	14.00	140.4	29.980	5.032	0.0533
40.00	45.00	134.	134.	240.	14.00	140.4	29.980	5.032	0.0533
45.00	50.00	134.	134.	240.	14.00	140.4	29.980	5.032	0.0533
50.00	55.00	134.	134.	235.	14.00	140.1	29.980	5.032	0.0537
55.00	60.00	134.	134.	240.	14.00	140.4	29.980	5.032	0.0533

FORM C7040 NAVFAC JET DUST SAMPLER TEST 7 DOWNSTREAM 14APR75 PAGE 6
04/23/75

QSSUM = 337.4626 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 213.9625 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 287.7871 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0062 GRAMS

CONC/ACF = 0.0003 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0004 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 8 UPSTREAM 15APR75 PAGE 1
04/23/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-527
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.06620 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.04540 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.02080 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.990 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 8 UPSTREAM 15APR75 PAGE 2
04/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	1.00	131.	131.	235.	5.50	137.8	29.990	4.648	0.0540
1.00	2.00	131.	131.	230.	5.50	137.5	29.990	4.648	0.0544
2.00	5.00	131.	131.	220.	5.50	136.9	29.990	4.648	0.0552
5.00	10.00	131.	131.	220.	5.50	136.9	29.990	4.648	0.0552
10.00	20.00	131.	131.	220.	5.50	136.9	29.990	4.648	0.0552
20.00	25.00	131.	131.	225.	5.50	137.2	29.990	4.648	0.0548
25.00	40.00	131.	131.	230.	5.50	137.5	29.990	4.648	0.0544
40.00	52.00	131.	131.	230.	5.50	137.5	29.990	4.648	0.0544
52.00	55.00	131.	131.	225.	5.50	137.2	29.990	4.648	0.0548
55.00	60.00	131.	131.	230.	5.50	137.5	29.990	4.648	0.0544

FORM C7040 NAVFAC JET DUST SAMPLER TEST 8 UPSTREAM 15APR75 PAGE 3
04/23/75

QSSUM = 209.4048 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 136.9256 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 180.2832 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0208 GRAMS

CONC/ACF = 0.0015 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0023 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

CONC/DUCT ACF = 0.0018 GRAINS PER CUBIC FOOT AT DUCT CONDITIONS, GR/DUCT ACF

FORM C7040 NAVFAC JET DUST SAMPLER TEST 8 DOWNSTREAM 15APR75 PAGE 1
04/23/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-526
PAD2

TOTAL FINAL PAD(S) WEIGHT	2.05100	GRAMS
TOTAL INITIAL PAD(S) WEIGHT	2.04440	GRAMS
TOTAL PAD(S) WEIGHT GAIN	0.00660	GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.990 IN HG

FORM C7040 NAVFAC JET DUST SAMPLER TEST 8 DOWNSTREAM 15APR75 PAGE 2
04/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	5.00	132.	132.	250.	14.00	139.4	29.990	4.773	0.0528
5.00	10.00	132.	132.	210.	14.00	137.1	29.990	4.773	0.0559
10.00	15.00	132.	132.	210.	14.00	137.1	29.990	4.773	0.0559
15.00	20.00	132.	132..	217.	14.00	137.5	29.990	4.773	0.0553
20.00	25.00	132.	132.	220.	14.00	137.7	29.990	4.773	0.0551
25.00	30.00	132.	132.	225.	14.00	138.0	29.990	4.773	0.0547
30.00	35.00	132.	132.	232.	14.00	138.4	29.990	4.773	0.0542
35.00	40.00	132.	132.	235.	14.00	138.5	29.990	4.773	0.0539
40.00	45.00	132.	132.	235.	14.00	138.5	29.990	4.773	0.0539
45.00	50.00	132.	132.	240.	14.00	138.8	29.990	4.773	0.0536
50.00	55.00	132.	132.	240.	14.00	138.8	29.990	4.773	0.0536
55.00	60.00	132.	132.	235.	14.00	138.5	29.990	4.773	0.0539

FORM C7040 NAVFAC JET DUST SAMPLER TEST 8 DOWNSTREAM 15APR75 PAGE 3
04/23/75

QSSUM = 334.9960 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 217.1509 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 287.8173 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

PAD WEIGHT GAIN = 0.0066 GRAMS

CONC/ACF = 0.0003 GRAINS PER CUBIC FOOT AT SAMPLER CONDITIONS, GR/ACF

CONC/DGSCF = 0.0005 GRAINS PER CU FT OF DRY GAS AT 70 DEG.F AND 29.92 IN HG

PEP-702
24 July 1975

Performance Evaluation
Conducted on a Two-Stage Electrocell Unit
Jet Engine Test Cell
Naval Air Station
Naval Air Rework Facility
Jacksonville, Florida

REPORT NO. 2

Report No. 2
24 July 1975

PURPOSE:

On July 14, 1975 a field trip was made to the Naval Air Station located in Jacksonville, Florida. The purpose of this trip was to complete the final performance tests on the two-stage Electrocell system installed on this facility's jet engine test cell. This series of tests was conducted to determine if any basic change in the systems' collection efficiency had occurred since the May, 1975 test program reported in PEP-702.

BACKGROUND:

Upon arrival at the test site, a quick inspection revealed the cells were dirty, therefore requiring a wash cycle prior to AAF tests. Upon completion of this wash (accomplished by use of a new proto-type washing control installed by Mr. Doug Pfeiffer of AAF) the system was deemed ready for efficiency testing.

TESTS & RESULTS:

A series of two tests were conducted on the system utilizing the same equipment, procedures and techniques as employed during the May, 1975 program. However these tests were conducted at one system volume only, instead of several various flows as was previously the case.

The system air volume was set at 7334.1 CFM utilizing the 36 square inch inlet plate which provides a cell velocity of 501 FPM. With all other factors the same as the May tests, this recent series provided inlet concentrations of 0.0012162 and 0.0022618 grains per cubic foot for tests 1 and 2 versus 0.0001766 and 0.0001612 grains per cubic foot for the respective outlets. The values provide an average collection efficiency of 89.1% very close to the original test average of 90.4%. (Test data are recorded in Table 1, and followed by computer print outs.)

CONCLUSIONS:

Since the basic purpose was to determine changes or alterations in the ECU's performance at the selected velocity of 501 FPM, these test results provide evidence of the system's continuous efficient operation at this velocity.

Richard P. Williams
RICHARD P. WILLIAMS

RPW:ws

cc: P. Rayner K. Westlin J. Wiegel C. Bressoud
Welch J. Ashe PEP-702

TABLE 1

Date of Test	7/15/75	7/15/75
Test Number	1	2
Actual Test Time	9:32-10:22	10:59-11:59
Orifice Size, in^2	36	36
Engine RPM (avg.)	7003	7000
Thrust (avg.)	7320	7355
Fuel Flow	6058	6061
E.G.T. (avg.)	992	987
Ambient Temp °F	81	83
Inlet Duct Temp °F	120-132	132
Barometric Pressure, in Hg	30.08	30.08
Total Air Volume , CFM	7334.1	7334.1
Duct Velocity, FPM	733.4	733.4
Cell Velocity, FPM	501.3	501.3
Inlet Conc, grs/ft^3	0.0012162	0.0022618
Outlet Conc, grs/ft^3	0.0001766	0.0001612
System Efficiency, %	85.48	92.87

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-561
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.06990 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.05570 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.01420 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.920 IN HG

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	1.00	130.	130.	240.	5.80	137.3	29.920	4.526	0.0536
1.00	2.00	131.	131.	235.	5.80	137.7	29.920	4.648	0.0539
2.00	4.00	131.	131.	230.	5.80	137.4	29.920	4.648	0.0543
4.00	6.00	131.	131.	225.	5.80	137.1	29.920	4.648	0.0547
6.00	12.00	132.	132.	230.	5.80	138.2	29.920	4.773	0.0542
12.00	40.00	132.	132.	230.	5.80	138.2	29.920	4.773	0.0542
40.00	45.00	132.	132.	235.	5.80	138.5	29.920	4.773	0.0538
45.00	50.00	132.	132.	235.	5.80	138.5	29.920	4.773	0.0538

QSSUM = 180.1515 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 116.1765 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 154.2685 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-562
PAD2

TOTAL FINAL [illegible](S) WEIGHT 2.05940 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.05620 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00320 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.920 IN HG

FORM C7040 DOWNSTREAM TEST 1 PAGE 2
07/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	2.00	132.	132.	240.	14.00	138.8	29.920	4.773	0.0534
2.00	5.00	132.	132.	230.	14.00	138.2	29.920	4.773	0.0542
5.00	10.00	132.	132.	235.	14.00	138.5	29.920	4.773	0.0538
10.00	12.00	132.	132.	240.	14.00	138.8	29.920	4.773	0.0534
12.00	15.00	132.	132.	235.	14.00	138.5	29.920	4.773	0.0538
15.00	20.00	132.	132.	230.	14.00	138.2	29.920	4.773	0.0542
20.00	22.00	132.	132.	225.	14.00	137.9	29.920	4.773	0.0546
22.00	25.00	132.	132.	230.	14.00	138.2	29.920	4.773	0.0542
25.00	30.00	132.	132.	225.	14.00	137.9	29.920	4.773	0.0546
30.00	50.00	132.	132.	225.	14.00	137.9	29.920	4.773	0.0546

FORM C7040 DOWNSTREAM TEST 1 PAGE 3
07/23/75

UM = 279.4835 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

DSUM = 180.6879 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

DDASUM= 240.1550 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

FORM C7040 UPSTREAM TEST 2 PAGE 1
07/23/75

TEST DATA

CONCENTRATION DETERMINATION MADE USING A

FIVE INCH SAMPLER WITH A ONE-FOURTH INCH ORIFICE

CARRIER GAS: AIR

TEST PAD(S)

PAD1 CT-563
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.10940 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.07780 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.03160 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.920 IN HG

FORM C7040 UPSTREAM TEST 2 PAGE 2
07/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	1.00	132.	132.	250.	5.80	139.4	29.920	4.773	0.0527
1.00	2.00	132.	132.	260.	5.80	139.9	29.920	4.773	0.0520
2.00	3.00	132.	132.	250.	5.80	139.4	29.920	4.773	0.0527
3.00	5.00	132.	132.	240.	5.80	138.8	29.920	4.773	0.0534
5.00	6.00	132.	132.	230.	5.80	138.2	29.920	4.773	0.0542
6.00	7.00	132.	132.	225.	5.80	137.9	29.920	4.773	0.0546
7.00	30.00	132.	132.	225.	5.80	137.9	29.920	4.773	0.0546
30.00	60.00	132.	132.	225.	5.80	137.9	29.920	4.773	0.0546

FORM C7040 UPSTREAM TEST 2 PAGE 3
07/23/75

QSSUM = 215.5737 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS., ACF

QDSUM = 139.7585 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

QDASUM= 185.7551 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

TEST PAD(S)

PAD1 CT-564
PAD2

TOTAL FINAL PAD(S) WEIGHT 2.08010 GRAMS
TOTAL INITIAL PAD(S) WEIGHT 2.07660 GRAMS
TOTAL PAD(S) WEIGHT GAIN 0.00350 GRAMS

BAROMETRIC PRESSURE ABSOLUTE 29.920 IN HG

FORM C7040 DOWNSTREAM TEST 2 PAGE 2
07/23/75

TIME1	TIME2	DUCT DB	DUCT WB	SAMPLER DB	OPD	SAMPLER WB	PSAH	PPWH	DENS
0.00	2.50	132.	132.	250.	14.00	139.4	29.920	4.773	0.0527
2.50	2.50	132.	132.	270.	14.00	140.5	29.920	4.773	0.0513
2.50	4.00	132.	132.	260.	14.00	139.9	29.920	4.773	0.0520
4.00	6.00	132.	132.	250.	14.00	139.4	29.920	4.773	0.0527
6.00	7.00	132.	132.	240.	14.00	138.8	29.920	4.773	0.0534
7.00	9.00	132.	132.	230.	14.00	138.2	29.920	4.773	0.0542
9.00	11.00	132.	132.	220.	14.00	137.7	29.920	4.773	0.0550
11.00	15.00	132.	132.	215.	14.00	137.4	29.920	4.773	0.0554
15.00	25.00	132.	132.	220.	14.00	137.7	29.920	4.773	0.0550
25.00	30.00	132.	132.	222.	14.00	137.8	29.920	4.773	0.0548
30.00	35.00	132.	132.	225.	14.00	137.9	29.920	4.773	0.0546
35.00	42.00	132.	132.	226.	14.00	138.0	29.920	4.773	0.0545
42.00	45.00	132.	132.	225.	14.00	137.9	29.920	4.773	0.0546
45.00	50.00	132.	132.	226.	14.00	138.0	29.920	4.773	0.0545
50.00	55.00	132.	132.	227.	14.00	138.1	29.920	4.773	0.0544
55.00	60.00	132.	132.	226.	14.00	138.0	29.920	4.773	0.0545

FORM C7040 DOWNSTREAM TEST 2 PAGE 3
07/23/75

.UM = 334.8472 TOTAL ACTUAL SAMPLED VOLUME AT SAMPLER TEMP. AND PRESS.. ACF

DDSUM = 217.1904 TOTAL DRY GAS SAMPLED VOLUME AT 70 DEG.F AND 29.92 IN HG

DASUM= 288.6711 TOTAL ACTUAL SAMPLED VOLUME AT DUCT TEMP. AND PRESS.

APPENDIX A-2

Air Samples from Electrostatic Precipitators;

Results of;

Naval Air Rework Facility, NAS

Jacksonville, Florida

TO R Hanson

Code 340
16 Jun 1975

MEMORANDUM

From: Code 340
To: Code 610

Subj: Air samples from Electrostatic Precipitator; results of

Ref: (a) MELR No. 3-74

Encl: (1) J-79 engine data with electrostatic precipitator
(2) J-52 engine data with electrostatic precipitator
J-52 engine data without electrostatic precipitator activated

1. Air sampling for determining the efficiency of an electrostatic precipitator has been performed on the NARF model as required by United Engineers and Constructors, Incorporated, for SOUDIVNAVFAC.

2. The test results are forwarded as enclosures (1) and (2). The following information concerns the data:

a. The format and calculations are those used in reference (a) in order to allow comparison of similar data.

b. All tests were performed at normal rated power.

c. The model exhaust gas entrance tube was blanked off between the April and June tests.

d. The precipitator was cleaned in April after the J-79 tests and not thereafter.

e. The June 4 tests were made with both power packs on the precipitator activated.

f. The June 5 tests were made with one power pack nonfunctional.

g. The June 6 morning and afternoon tests were made with no power to the precipitator.

F. W. THOMAS
Superintendent

J-79 ENGINE DATA WITH ELECTROSTATIC PRECIPITATOR

	INLET	OUTLET	INLET	OUTLET	INLET	OUTLET
Date	4-17	4-17	4-18 AM	4-18 AM	4-18 PM	4-18 PM
Flow at #1 Sump gal./min.	9.66		9.89		9.61	
Vol. of dry gas sampled, SCF	92.79	81.66	87.99	83.31	84.27	84.82
Stack flow rate, SCFM, dry	9276.0	8149.4	8404.3	7621.5	8607.6	7920.2
Stack gas velocity, at stack conditions, f.p.m.	763.8	665.8	703.8	620.5	698.0	698.3
Moisture, % by volume	15.75	15.15	17.13	14.89	16.66	15.39
Stack gas temp. degree F.	132	131	132	131	132	131
Isokinetic, %	97.5	97.6	102.0	106.0	95.0	104.3
Particulate Results						
(a) Probe and filter catch Grains/SCF, dry, x 10^{-3}	6.17	2.90	3.48	1.05	3.14	1.05
(b) Total Catch Grains/SCF, dry, x 10^{-3}	7.30	3.54	3.92	1.20	3.21	1.27
(c) Particulates from #1 Sump Water sample grains/SCF, x 10^{-3}	5.41		5.64		5.14	
Particulate Removal Efficiency						
Based on air sample (a), %	53.0		69.8		66.6	
Based on air sample (b), %	51.5		64.9		60.4	
Based on total (air and water, a+c), %	74.9		88.5		87.3	
Based on total (air and water b+c), %	72.1		86.8		84.8	
Entrained Water Removal, %	11.5		44.8		22.7	

Enclosure (1)

J-52 ENGINE DATA WITH ELECTROSTATIC PRECIPITATOR

	INLET	OUTLET	INLET	OUTLET
Date	6-4	6-4	6-5	6-5
Flow at #1 Sump gal./min.	10.84		9.92	
Vol. of dry gas sampled, SCF	81.329	77.942	80.930	78.660
Stack flow rate, SCFM, dry	7552.8	7302.7	8339.9	7409.9
Stack gas velocity, at stack conditions, f.p.m.	682.5	609.9	693.5	611.1
Moisture, % by volume	18.66	16.65	16.24	15.65
Stack gas temp. degree F.	133	131	132	131
Isokinetic, %	99.6	104.0	94.5	103.4
Particulate Results				
(a) Probe and filter catch Grains/SCF, dry, x 10^{-3}	1.44	2.65	1.26	1.37
(b) Total Catch Grains/SCF, dry, x 10^{-3}	1.91	3.44	1.56	1.92
(c) Particulates from #1 Sump Water sample grains/SCF, x 10^{-3}	1.02		0.97	
Particulate Removal Efficiency				
Based on air sample (a), %	-84.03		-8.73	
Based on air sample (b), %	-80.10		-23.08	
Based on total (air and water, a+c), %	-7.72		38.56	
Based on total (air and water, b+c), %	-17.41		24.11	
Entrained Water Removal, %	27.34		9.50	

Enclosure (2)

J-52 ENGINE DATA WITHOUT ELECTROSTATIC PRECIPITATOR ACTIVATED

	INLET	OUTLET	INLET	OUTLET
Date	6-6 AM	6-6 AM	6-6 PM	6-6 PM
Flow at #1 Sump gal./min.	10.34		10.34	
Vol of dry gas sampled, SCF	82.395	79.456	85.549	79.521
Stack flow rate, SCFM, dry	8265.7	7358.0	8270.8	7466.1
Stack gas velocity, at stack conditions, f.p.m.	698.7	614.5	697.3	622.4
Moisture, % by volume	17.24	16.32	16.82	15.98
Stack gas temp. degree F.	133	132	133	132
Isokinetic, %	97.1	105.2	100.8	103.8
Particulate Results				
(a) Probe and filter catch Grains/SCF, dry, x 10^{-3}	1.53	1.92	1.49	1.90
(b) Total Catch Grains/SCF, dry, x 10^{-3}	1.92	2.40	1.99	1.90
(c) Particulates from #1 Sump Water sample grains/SCF, x 10^{-3}	1.02		0.93	
Particulate Removal Efficiency				
Based on air sample (a), %	-25.49		-27.52	
Based on air sample (b), %	-25.00		-19.60	
Based on total (air and water, a+c), %	24.71		21.49	
Based on total (air and water, b+c), %	18.37		18.49	
Entrained Water Removal, %	15.60		15.37	

Enclosure (2)

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GENERAL COMPUTATION SHEET

united engineers & constructors inc.

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CALC. SET NO.		
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VOID		
SHEET	OF	
J.O. 6183-003		
REV	COMP. BY	CHK'D BY
0	DAM DATE	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype Recip UNIT/S

SUBJECT Correction of NARF-Jax Data Sin. Duct Stk.

- NARF CALC. OF STACK Flowrate appears to be based on $16 FT^2$ duct instead of $10 FT^2$ stack

1C Term of 4-17 Inlet

VEL = 763.8 FPM

ACFM using $16 FT^2$ stack = (763.8)(16) = 12,220.8 ACFM

Dry ACFM @ 15.75% H_2O = (12,220.8)(1 - .1575) = 10,296 DACFM

Dry SCFM @ 70°F = $(10,296)\left(\frac{530°R}{(460+132)}\right)$ = 9217 SCFM, dry

Report lists 9276 ACFM, difference is probably due to static press. which was not listed.

- Actual duct dimension are 4 × 2'-6 = $10 FT^2$
∴ Stack Flowrate dimensions should be corrected by 10/16 = 0.625

- Data listed under Particulate results (c) (Particulates from #1 sump) are calculated as follows

Conc = (Gr/GAL)(GAL/min)

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J.O. 6163-005	

REV	COMP. BY	CHK'D BY
0	Dan DATE	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype Recip UNIT/S

SUBJECT Correction of NARF-Jax Data of Duct Size

Therefore, this data must be corrected by 16/10 = 1.6

- Data listed under Particulate Removal Efficiency must be corrected to reflect higher concentrations

- Data corrected as follows.

		4-17	4-18 AM	4-18 PM	6-4	6-5	6-6 AM	6-6 PM
DATE		4-17	4-18 AM	4-18 PM	6-4	6-5	6-6 AM	6-6 PM
Location		inlet	inlet	inlet	inlet	inlet	inlet	inlet
Stack Vel	Report	9276	8404	8608	7953	8340	8266	8271
	Corr.	5798	5253	5380	4971	5713	5166	5169
Part from #1 Samp	Report	.00541	.00564	.00514	.00102	.00097	.00102	.00093
	Corr	.00866	.00902	.00822	.00163	.00155	.00163	.00149
Efficiency based on inlet + outlet (b+c)	Report	72.1	86.8	84.8	-17.41	24.11	18.37	18.49
	Corr	77.8	90.73	88.89	2.82	33.52	32.4	31.6

APPENDIX A-3

Basis for Operating Cost Computations

45<

5017-BOS

united engineers & constructors inc. a subsidiary of Raytheon Company

Prepared DAW Date

Checked Date

Record No. 6183-003.2

PARAMET...
ENGINE TE...

	ENGINE PARAMETERS				TEST CELL PARAMETERS		
	POWER LVL	ENGINE Exh Flow	ENGINE Exh TEMP		AUG RATIO	CELL Flow	CELL Exh Temp
	—	lb/SEC	°F		—	lb/SEC	°F
J79 ENGINE w/AB	IDLE	50	350		.5	75	275
	75% MAX	170	1000		.9	323	600
	MIL	170	1150		1.0	340	625
	AB	170	3100		1.2	374	1550
350 lb/SEC ENGINE w/AB	IDLE	130	350		1	260	215
	70%	240	500		1	480	292
	100%	350	650		1	700	380
	AB	350	3500		1.2	770	1690

METERS FOR TYPICAL
E TEST CYCLE

Evaporative Cooling: Evaporation @ Sat	Sat. Temp	Sat Gas Flow	Evaporation Rate	Coolant Pumping Rate	Gas Cleaning: Precip Demand	Time at Power	Coolant Pumped	Coolant Evap	Overspray
lb H2O/lb gas flow	°F	ACFM	GPM	GPM	KW	min	GAL	GAL	GAL
0.04	100	67,500	22	50	28	50	1100	2500	1400
0.12	130	340,000	280	350	26	30	8400	10,500	2100
0.135	132	362,000	331	425	28	30	9900	12,750	2850
0.35	164	547,000	943	1700	28	10	9430	12,000	2570
						120 min	37,760	28030	8920
0.03	87	225,000	56	70		55	3850	3080	770
0.05	105	440,000	173	220		30	6600	5200	1400
0.07	112	666,000	355	450		30	13500	10,950	2550
0.38	167	1175,000	2053	2600		22	57,200	45,200	12,000
						137 min	81,100	64430	16,720

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SHEET 1 OF 1	
J.O. 6133-003	

REV	COMP. BY	CHK'D BY
0	[illegible] DATE 7-9-75	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC [illegible] UNIT/S

SUBJECT Cost of [illegible] Energization

I 500,000 [illegible] unit

Consists of 5 modules

Each module contains 56 cells (8 wide x 7 high)

Each horizontal Row (8 wide) supplied by one LG-8

Power Pack. Rating 6.5 A @ 120VAC, 500W

System will operate at rating per AAF

$Kw = (7\ rows/module)(8\ module)(.5\ Kw/Row) = \underline{28\ Kw}$

For 120 min test cycle → 28 kw x 2hrs = 56 Kwh

@ $.03/Kwh = $1.68

II 1,200,000 ACFM unit

Consists of 16 modules

Each module contains 64 cells (8 x 8)

Each row supplied by one LG-8 Power Pack

$Kw = (8\ rows/module)(16\ modules)(.5\ Kw/Row) = \underline{64\ Kw}$

For 137 min TEST cycle → 64 Kw x 137/60 = 146 Kwh

@ $.03/Kwh = $4.38

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J.O. 6183-003		
REV	COMP. BY	CHK'D BY
0	Dam DATE 7-4-75	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype Program UNIT/S

SUBJECT Cost of Evaporative Cooling

I Water Consumption

500,000 ACFM - 28,830 GAL

1,200,000 ACFM - 64,430 GAL

II. Pumping Power

300' HD, 60% Pump Eff, 90% Motor Eff.

$$\text{Kwh/1000 Gal} = \frac{(0.00315)(300)(1)}{(0.6)(0.9)} = 1.76$$

500,000 ACFM - 37,750 Gal Pumped

Kwh = (37.75)(1.76) = 66.44

1,200,000 ACFM - 81,100 Gal Pumped

Kwh = (81.1)(1.76) = 142.74

III. Summary

Item	Consumption	Rate	Cost
Water	28,830 Gal	$.35/1000 Gal	$10.09
Power	66.44 Kwh	$.03/Kwh	1.99
Total			$12.08
Water	64430	$.35/1000 Gal	22.55
Power	142.74	$.03/Kwh	4.28
Total			$26.83

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SHEET 1 OF 1	
J.O. [illegible]-003	

REV	COMP. BY	CHK'D BY
0	[illegible] DATE 7-4-7[illegible]	DATE
	DATE	DATE

NAME OF COMPANY [illegible] UNIT/S

SUBJECT Cost of Overseas / Reclamation

I. Pumping Costs

35' HD, 50% Pump Eff, 85% [illegible] Eff

$$\text{kwh}/[\text{illegible}] = \frac{(0.[\text{illegible}])(35)(1)}{(.5)(.85)} = 0.259$$

500,000 ACFM - 8920 Gal Pumped

kwh = (.259)(892) = 231

1,000,000 ACFM - 16720 Gal Pumped

kwh = (.259)(1672) = 433

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SHEET 1 OF 4		
J.O. 6183-005		
REV	COMP. BY	CHK'D BY
0	DGH DATE 7-4-71	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC [illegible] UNIT/S

SUBJECT Cost of Washing Precipitator

I. Water Consumption during wash cycle

- Each washer assembly consumes 15 GPM when in operation
- Washer nozzles travel 6FT/min vertically; assemblies travel 6FT/min horizontally
- Washer nozzles make 4 vertical passes; assemblies (4' o [illegible]) then index horizontally

500,000 ACFM Total time vertically - 12FT high module / 6 FT/min × 4 passes × 24' wide / 4'-0 wide assy = 48 min

horizontally = 24' wide / 4'-0 wide assy = 6 min

TOTAL - 54 min/module

Nozzles operate only during vertical passes

Consumption = 15 Gpm/assy × 8 assy × 48 min = 5760 Gallons

1,200,000 ACFM - Total time - vertically - 13FT high module / 6FT/min × 4 passes × 24' wide / 4' wide assy = 52 min

horizontally 6 min

Total 58 min

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FINAL		
VOID		
SHEET 2 OF 4		
J.O. 6183-003		
REV	COMP. BY	CHK'D BY
0	DGW DATE 1-4-??	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC [illegible] UNIT/S

SUBJECT Cost of washing Precipitator

Consumption = 15 GPM/assy × 16 assy × 52 min = 12,500 GALL

II. ENERGY COST OF WASHER DRIVES

1/6 HP drive motors operating for 54 min (1 for 48, 1 for 6)

assume .15 Kw input

500,000 ACFM - [illegible] = 0.15 Kw × 8 modules × 54 min = 1.09 Kwh

1200,000 ACFM - [illegible] - 0.15 Kw × 16 modules × 58 min = 2.33 Kwh

III ENERGY COST OF [illegible] wash water

$$\text{Kwh/1000 GAL} = \frac{(0.00315)(\text{hd})(\text{sp.gr.})}{(\text{pump eff})(\text{motor eff})}$$

500,000 ACFM - 5760 GALL

$$\text{Kwh/1000 GAL} = \frac{(0.00315)(100')(1)}{(0.6)(0.85)} = 0.618$$

$$\text{Kwh} = (.618)(5.76) = \underline{3.5}$$

1200,000 ACFM - 13,500 GAL

$$\text{Kwh/1000 GAL} = \frac{(0.00315)(140)(1)}{(0.6)(0.85)} = 0.866$$

$$\text{Kwh} = (0.866)(13.5) = \underline{11.8}$$

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J.O. 6183-003		
REV	COMP. BY	CHK'D BY
0	Dan \ DATE 7-4-75	DATE
	DATE	DATE

NAME OF COMPANY [illegible] UNIT/S

SUBJECT Cost of Washing Keep

II Detergent Consumption

Detergent is used at ratio of 40:1

during 2 of 4 washing [illegible] ·

[illegible] consumption = 5760 gal × 1/2 cycle × $\frac{1}{40}$ = 72 gal

1,000,000 [illegible] Consumption 12500 gal × 1/2 cycle × $\frac{1}{40}$ = 156.25 gal

V Summary

	Item	Consumption	Unit	Cost	
J79	water	5800 gal	\$.35/1000 gal	\$2.03	
	detergent	72 gal	\$4.00/gal	\$288	
	power	4.59 kwh	\$.03/kwh	\$0.14	
	Total			\$290.17	Per complete wash
350 lb/sec	water	12,500 gal	\$.35/1000 gal	4.38	
	detergent	156 gal	\$4.00/gal	\$624	
	power	14.13 kwh	\$.03/kwh	\$0.42	
	Total			\$628.80	Per complete wash

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J.O. 6183-003	

REV	COMP. BY	CHK'D BY
0	DBL DATE 7-4-75	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype UNIT/S

SUBJECT Cost of washing Precipitator

- Estimate of Precip wash schedule

  1st week - once per week - (10 Tests)

  2nd week - once per day (40 Tests)

- Number of Tests per complete wash

  1 + (3)(1/2) = 2 1/2 washes per 40 Tests = 16

- Cost per Test

  500,000 ACFM - \$290.17/16 = \$18.14/Test

  1200,000 ACFM - \$628.80/16 = \$39.30/Test

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J.O. 6183-003	

REV	COMP. BY	CHK'D BY
0	Dbm DATE 7-11-??	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype Kreal UNIT/S

SUBJECT Operating Costs of Pressure Filter System

I. Maximum Total Particulates Generated

(1) Estimate fuel flow per engine

(2) Use emission factors from Report

– J79 engine in 120 min cycle

Power Lvl	Thrust	TSFC	Fuel Flow	Emission Factor	Time @ Power	10^6 Btu burned	lbs Part Gen
IDLE	410 lb	3.95	1620 pph	1.7 lb/10^6 Btu	50 min	25	42.5
INT	7300	.82	6000 pph	1.0 "	30 min	55.5	55.5
MIL	10,000 lb	.86	9375 pph	1.0 "	30 min	86.7	86.7
AB	17,000 lb	1.93	32,800 pph	.4 "	10 min	101.2	40.5
							225.2 lbs per test

– 350 lb/sec engine in 137 min cycle

IDLE	900	1.6	1440 pph	1.2	55 min	24.29	29.1
INT	9,300	.6	5580 pph	.5	30 "	51.34	25.7
MIL	19,400	.65	12,610 pph	.5	30 "	116.01	58
AB	29,400	3	88,200	.3	22 "	595.06	178.5
							291.3 lbs per test

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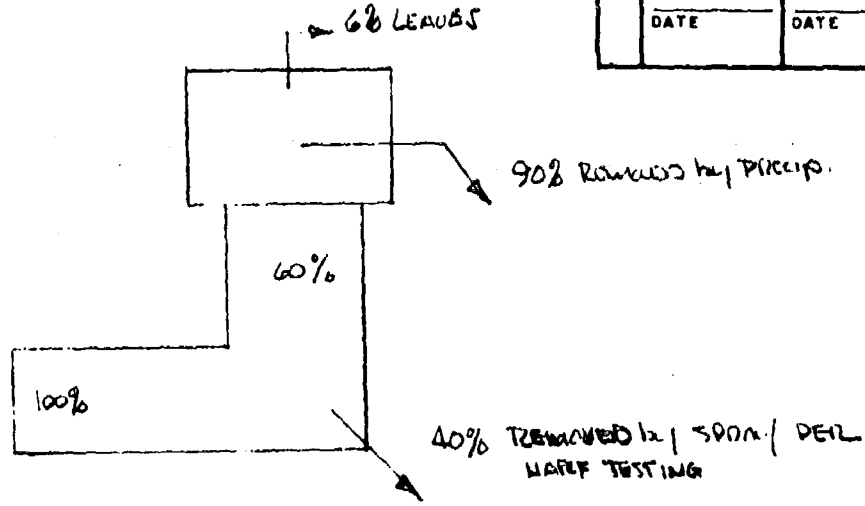
J.O. 6153-003		
REV	COMP. BY	CHK'D BY
0	Dbm DATE 7-11-75	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Wilkins Assoc. UNIT/S.

SUBJECT Operating Cost / Pressure Filter System

II. Distribution of Particulates



Total pollutants collected per test -

J79 - 225.2 x .94 = 211.7 lbs

350 lb/sec - 291.3 x .94 = 273.8 lbs

III. Operating Cost Factors (Excluding Pumping)

1) Filter aid is added at a rate of between 0.1 and 1.0 lb/lb particulate during filtering

2) Filter is precoated with filter aid after every cleaning (0.1 lb/sqft)

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VOID	
SHEET 3 OF 4	
J.O. 6183-003	

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0	Dan DATE 7-11-76	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC [illegible] UNIT/S

SUBJECT Operating Costs of Pressure Filter System

4, Cleaning requires approx 10,000 SCF of air for drying (800 sq ft unit)

5, Cleaning requires approx 3-5 SCFM for approx 15 min to operate leaf vibrators

Using 800 sq ft filter, a total of approx 1400 lbs part could be collected between cleanings based on additional lb filter aid / lb part.

Per cleaning: Total filter aid added with slurry = 1400 lbs

" " " " " Precoat = 80

1480 lbs @ 12.5¢/lb

\$185

Total air to dry = 10,000 SCF

Air to vibrate: 5 scfm · 15 min = 75 SCF neglect

Say 10,000 SCF @ \$.20/1000 CF

= \$2.00

\$187 / cleaning

+ ½ mh labor

For J79, filter would be cleaned twice every 10-12 tests once prior to and following pickup wash.

For 350 lb/sec, twice every 8-10 tests

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J.O. 6183-123		
REV	COMP. BY	CHK'D BY
0	DATE 7-11-76	DATE
	DATE	DATE

NAME OF COMPANY [illegible] UNIT/S

SUBJECT [illegible] PRESSURE FILTER SYSTEMS

IV. Pumping Costs (on per year basis)

avg pumphead [illegible]

$$\text{Kwh/1000 gal} = \frac{(0.08315)(10)(1)}{(5.6)(.85)} = 0.618$$

500,000 ACFM - 8420 gal / year

Kwh = (0.618)(8.92) = 5.51

1,200,000 ACFM

Kwh = (0.618)(16.72) = 10.33

APPENDIX A-4

Conversion Test Data to

Emission Factors

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SHEET 1 OF 4	
J.O. 6183-003	

REV	COMP. BY	CHK'D BY
0	DG DATE 7-7-78	DG DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype Precip UNIT/S

SUBJECT Conversion of Test Data to lbs/10^6 Btu

I. Fuel Heat Input

Average Engine Fuel Flow during Tests - 6000 lbs/HR

Fuel Heating Value - 18,400 Btu/lb

Fuel Heat input = (18,400)(6000) = 110.4 $\times 10^6$ Btu/HR

II. Total Gas Flow

- Estimated Engine Air ingestion @ Takeoff = 180 lb/sec
- Fuel Flow = 6000 lbs/hr / 3600 sec/hr = 1.67 lb/sec
- Total exhaust products = 181.67 lb/sec
- with Average tailpipe temp = 1000°F and saturation temp in stack = 130°F ; Augmentation ratio = 0.9
- Total Cell Flow = $\left(\frac{1. + 0.9}{1}\right)(181.7) = 345.2$ lb/sec

III Total [illegible] Cell Flow

- Moisture in Fuel

Assume 10% H_2 in fuel ; 0% free H_2O

lbs H_2O / H_2 = 8.94

59<

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NAME OF COMPANY NAVFAC Prokt/pe Vinsky UNIT/S

SUBJECT Conversion of Test Data to lbs/hr Dry

CALC. SET NO.	
PRELIM.	
FINAL	
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SHEET 2 OF 4	
J.O. 6183-23	

REV	COMP. BY	CHK'D BY
0	Don DATE 7-7-75	DATE
	DATE	DATE

Total H_2O injected = (0.844 lb/hr/lb fuel)

(6360 lb/hr)(1/3600 hr/sec) = 1.49 lb H_2O/sec

– moisture in ingested and augmented air

Total air = 345.2 – 1.67 = 343.5 lb/sec

Assume 0.013 lb H_2O/lb dry air

Total dry air = 343.5/1.013 = 339.2 lb/sec

Total air moisture = 343.5 – 339.2 = 4.3 lb/sec

– Dry gas flow

Total moisture = 1.49 + 4.3 = 5.79 lb/sec

Total dry gas = 345.2 – 5.79 = 339.4 lb/sec

density of dry gas @ 60°F, 29.92" Hg = 0.07636 lb/ft³

Total volume = (339.4 lb/sec)(60 sec/min)(1/.07636 lb/DSCF)

= 266,692 Dry SCFM

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J.O. 6183.003		
REV	COMP. BY	CHK'D BY
0	DATE 7-3-71	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Philadelphia Pittsburgh UNIT/S

SUBJECT Conversion of test data to lbs/10^6 Btu

IV Relationship between GR/DSCF and lbs/10^6 Btu

LET A = GR/DSCF (from test data)

lbs particulate/HR = (A GR/DSCF)(1/7000 lb/GR)(266,692 DSCF/min)(60 min/HR) = 2286 A lbs/HR

$$\text{lbs PART}/10^6\text{ Btu} = \frac{2286\text{ A lbs/HR}}{110.4\ 10^6\text{ Btu/HR}} = 20.71\text{ A}$$

V Data Conversion

- Maximum inlet concentration recorded in Type 'A' Tests

TESTS = 0.0045 GR/DSCF (4-9-75) , minimum = 0.0018

lbs/10^6 Btu = (.0045)(20.71) = 0.093   0.037

- Maximum outlet concentration recorded in Type 'A' Tests.

TESTS = 0.0008 GR/DSCF (4-9-75)   minimum = 0.0001

lbs/10^6 Btu = (0.0008)(20.71) = .017   0.002

61<

- Maximum inlet concentration recorded in Type 'B'

TESTS = 0.0073 + 0.00866 = 0.01596 GR/DSCF (4-17-75) ; minimum = 0.0114

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VOID	
SHEET 4 OF 4	
J.O. 6183-003	

REV	COMP. BY	CHK'D BY
0	Dam DATE 7-3-7	DATE
	DATE	DATE

NAME OF COMPANY NAVFAC Prototype Precip. UNIT/S

SUBJECT Conversion of Test Data to lbs/10^6 Btu

- maximum outlet concentration recorded in Type 'B' tests

= 0.00354 gr/dscf minimum 0.00120

lbs/10^6 Btu = (0.00354)(20.71) = <u>0.073</u> <u>0.025</u>

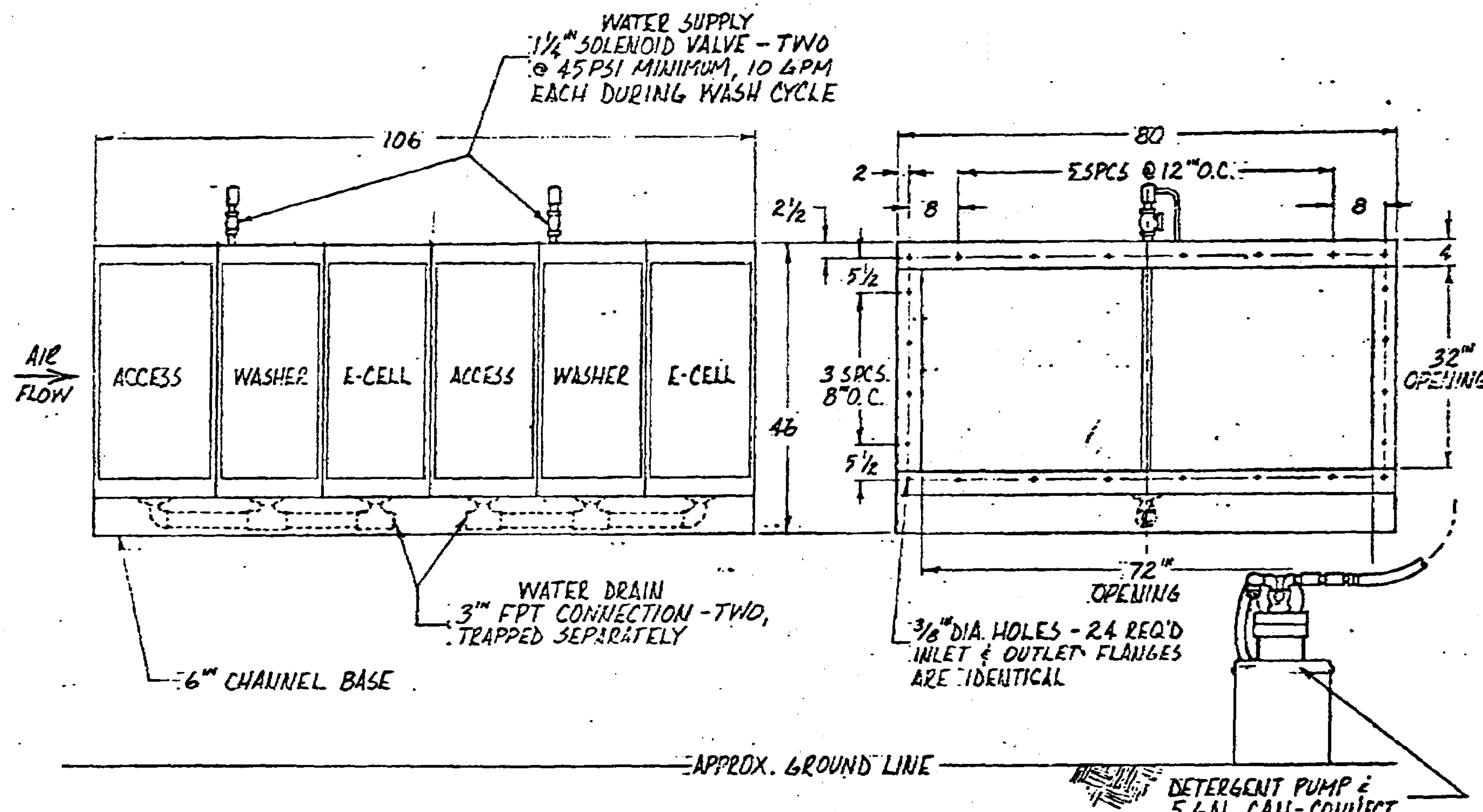
APPENDIX A-5

Dimensional Drawing

of

Two-Stage

Electrostatic Precipitator



RECOMMEND FOUR FEET CLEARANCE ON BOTH SIDES OF UNIT FOR SERVICING.

REVISIONS

SCALE ½" = 1'0"
DATE 14 MAR. 74
DWN.
CK'D
APPR.

AMERICAN AIR FILTER COMPANY, INC.
RESEARCH LABORATORY — LOUISVILLE, KY.

ELECTROSTATIC COLLECTOR FOR JET ENGINE TEST STAND (6H34)

DRAWING NO. DEV-835 (A)

SECTION 7

BIBLIOGRAPHY

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